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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

PROGRAMME OF THE

1955 TORONTO MEETING

AT

TORONTO, CANADA

with the

CANADIAN ASSOCIATION OF PHYSICISTS

June 22–23–24, 1955

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June 22, 1955 Vol. 30, No. 4

BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

1955 JUNE MEETING AT TORONTO, CANADA, JUNE 22, 23, and 24, 1955

THE **American Physical Society and the Canadian Association of Physicists will hold a joint meeting** in the buildings of the University of Toronto, Toronto, Canada, on Wednesday, Thursday, and Friday, **June 22, 23, and 24, 1955.** For our Society this will be the regular "Summer Meeting in the East," held this year in Canada for the first time since 1947. Contributed ten-minute papers of the Society and the Association are intermingled in our sessions. The invited papers of these three days were bespoken by the Society or by its Division of Electron Physics, of which latter this is the major meeting of the year; the Division has also taken an obviously successful part in evoking ten-minute papers in its field. The Association begins its meetings two days before ours; on Monday and Tuesday it will present symposia on radiations as applied to medicine, and on physics in industry—also the address of President Larkin Kerwin. For information as to these events and more, write to Professor B. W. Sargent (Queen's University, Kingston, Ontario) and ask him for a programme.

Professor H. J. C. Ireton of the University of Toronto is serving as Chairman of the Local Committee, and to him and his aides our gratitude is due.

The **registration desk** will be located in the McLennan Laboratory of the University of Toronto. Members of the Society, Members of the Association, and guests are asked to register. Members of the Society and guests are asked to pay the modest registration fee of one dollar; but from this are exempted the members of the Association who have previously paid the registration fee of their own meeting. One or more blackboards near the desk will carry notices of messages, of post-deadline papers if any, and other information.

The **names of hotels,** and the prices quoted to us, are reproduced from the Washington Bulletin: King Edward, $6.85 up (single) and $10.85 up (double); Park Plaza, $10 and $12; Windsor Arms, $7 and $9; Westminster, $7 and $12; Westmoreland, $6.50 and $11; Frontenac Arms, $6 and $10; Royal York, $9 up and $12.30 up. As these are in various parts of the city, we do not attempt to give the routes from any of them to the University: we are advised that it is best to go by taxi, and that the ride from any of the hotels (or from the Union Station) should not cost more than one dollar or last more than twenty minutes. Mention should perhaps be made of the unsurprising fact that Canadian money is used in Canada. The exchange is fluctuating, and of late the Canadian dollar has been slightly higher than the United States dollar. It must not be assumed that United States money will be accepted at par.

Those who wish to reside on the University campus should write—or should have written already—to Professor G. D. Scott, Department of Physics, University of Toronto, Toronto 5, Ontario. Here the prices are $3 per day per person. Other colleges have kindly offered space in their residence halls if those of the University are overtaxed.

Invited papers on the general (as distinguished from the Divisional) **programme** have been solicited from Canadian centers of research, from visiting British physicists, and from a few American universities not far from Toronto. The speakers are M. F. Crawford, P. Demers, A. E. Douglas, H. E. Duckworth, J. S. Foster, H. W. Fulbright, H. E. Gove, A. C. H. Hallett, P. Hartman, D. R. Hartree, G. Herzberg, F. A. Kaempffer, L. Katz, E. H. Kerner, S. A. Korff, P. Lorrain, J. M. Robson, J. Reekie, D. C. Rose, R. D. Russell, R. Skinner, H. G. Thode, and G. M. Volkoff.

Our **Division of Electron Physics** has arranged a programme of which the magnitude appeared to cause embarrassment to the Divisional officers themselves, forcing them to distribute its papers over six sessions instead of the contemplated five, and to begin the afternoon sessions at half-past one: electron physicists will have little leisure for the amenities of Toronto. The sessions of the Division, if not recognizable from the titles, may be identified

as those which are listed last in the account of each half-day. Ten-minute papers were put into the Divisional sessions whenever their authors so requested, and a few others were claimed by the Divisional officers. This has resulted in a peculiar situation in which not all of the papers on semiconductors are to be found in the session so named, nor all of the papers on low-temperature work in the session called cryogenics. It is hoped that these inconveniences are overcompensated by the unity of the Divisional scheme. Invited speakers on the Divisional programme are H. E. Farnsworth, P. A. Forsyth, A. R. Hutson, L. Kerwin, H. J. Krusemeyer, A. D. MacDonald, D. K. C. MacDonald, H. S. W. Massey, P. M. Millman, H. A. Reiss, and T. Holstein.

One hundred and fifty-five contributed papers are distributed among seventeen sessions. These make the Toronto meeting one of the largest Summer meetings that we have ever held.

The **banquet of the American Physical Society** will be held on Thursday evening (June 23) at seven o'clock in the Sheraton Room of the King Edward Hotel. We shall hope for the participation of officers and members of the Canadian Association of Physicists, both in the banquet and in the after-dinner programme. D. A. Keys will be one of the after-dinner speakers; others will be announced at the registration desk. The price of the banquet will be four dollars. Members are asked to make use of the reservation form on the inside back-cover page of the Bulletin. Tickets will be sold at the registration desk, and such as are reserved but not called for nor paid for by three P.M. on Thursday will be made available to the first comers.

The **University of Toronto** graciously invites the members and guests of the Society to **a reception** to be held on the Wednesday afternoon at half-past five, at 119 St. George Street.

The **Council of the American Physical Society** will meet at a time and place of which its members will be notified by special message.

Post-deadline ten-minute papers, pertaining to very recent achievements of very special importance, will be considered for admission to a special supplementary programme if the abstracts are received at the office of the Society not later than Friday, June 17. This being also the deadline date for the Mexico meeting, be sure to mark papers clearly! The titles of such as are accepted will be announced on a blackboard near the registration desk, and the papers will be given under the usual ten-minute rule at the end of Session Q. The abstracts will not be published. Those who submit post-deadline papers will not be able to find out whether their papers are admitted without coming to the meeting.

Preliminary announcements of the Mexico City and the Chicago meetings appear on pages 4 and 5 of this Bulletin, and the **calendar of meetings** (as far as now predictable) for the season 1955–1956 appears on page 6 with instructions for the preparation of abstracts.

General Rules Relating to Papers

The time allowed for the oral presentation of a contributed paper is ten minutes at most. The time allowed for the oral presentation of an invited paper is stated in the Bulletin. When two or more contributed papers are submitted by one author, or by more than one author with the same name appearing first in the by-line, all but one are placed on the "supplementary programme." For each paper on this programme a session is indicated, at the end of which the paper may be called for; but the Chairman of the session is empowered to limit it to fewer than ten minutes or to read it by title.

The abstracts of this Bulletin will reappear, precisely as they here stand, in an issue of *The Physical Review* appearing after the meeting. Errata will be printed on an adjacent page of *The Physical Review* if received not later than Friday, July 8, by Miss Ruth Bryans, 57 East 55th Street, New York 22, New York. Do not send in the text of the abstract marked with corrections! Write out the corrections in the form "instead of . . . read. . . ." Add nothing.

Karl K. Darrow, *Secretary*
American Physical Society
Columbia University
New York 27, New York

Second Announcement of the Mexico City Meeting

The 1955 August meeting of the American Physical Society, complementing the normal Summer Meeting in the East and supplanting the normal Summer Meeting in the West, will be held on Monday, Tuesday, and Wednesday, August 29, 30, and 31. This will be our first joint meeting with the Sociedad Mexicana de Física, and our first in the new buildings of the Universidad de México.

Hotel rooms are to be reserved by writing to Aguirre's Guest Tours, Luis Moya 5, México 1,

D.F., Mexico. This should be done promptly, with mention of the Society and with statement of the dates of your arrival and departure.

Abstracts of contributed ten-minute papers, prepared according to the usual regulations (see page 6), will be accepted from members of the Sociedad Mexicana de Física and from members of the American Physical Society, provided that they arrive not later than Friday, June seventeenth, at the address hereunder. Abstracts may be offered in English or in Spanish. Those received in Spanish will be rendered into English and published in this language in our Bulletin. Those received in English will be rendered into Spanish and distributed in that language by the Sociedad Mexicana de Física. For this latter purpose our members are specially asked to send original and *two* carbon copies of each abstract—three copies altogether!—to the address below; the third copy will be forwarded to Mexico.

KARL K. DARROW, *Secretary*
American Physical Society
Columbia University
New York 27, New York

Preliminary Announcement of the 1955 Thanksgiving Meeting

The 1955 Thanksgiving meeting of the American Physical Society will be held at the University of Chicago on Friday and Saturday, November 25 and 26, 1955. The Hotel Windermere, 1642 East 56th Street, Chicago 37, Illinois, will set aside rooms for our members, booking them in other neighboring hotels if there is need. Deadline will be Friday, September 23, and abstracts are to be sent to Karl K. Darrow, American Physical Society, Columbia University, New York 27, New York.

(Please keep this page on file!)

MEETINGS AND DEADLINES FOR THE SEASON 1955–1956

Place	*Meeting dates*	*Deadline date*
Mexico City	August 29–31	June 17
Chicago	November 25–26	September 23
Los Angeles	December 28–30	not decided
New York	January 31–February 4	not decided
Houston	February	not decided
Pittsburgh	March	not decided
Washington	April 26–28	not decided
New Haven	June 21–23	not decided
West Coast	June	not decided

RULES PRESCRIBED FOR ABSTRACTS

The Council has ordered that abstracts shall be not longer than two hundred (200) words or the equivalent thereof. In reckoning equivalence, a footnote is equated to ten words; each line in a table to ten words; a "display" formula—one that requires a line to itself—is an expensive luxury equated to forty words.

Two copies of each abstract must be sent to the appropriate office. They must be typewritten and double-spaced; one must be an original, the other may be an original or a carbon copy. Each abstract must be confined to a single page: if it is too long for a single page it is too long to be printed. Write each abstract as a single paragraph: the suppression of paragraphs costs time and labor to the editors. Do not use very thin paper; a sheet of very thin paper may cause extraordinary trouble when mixed with sheets of reasonable thickness. Look at the abstracts in this *Bulletin* to see how the title of the paper and the name of the author are to be arranged, and follow the example. Issues of the *Bulletin* are sometimes appreciably delayed because the editors have to do what the authors should have done.

Remember the rule of the Council that, if an author submits more than one abstract, all but one must go onto the Supplementary Programme. In enforcing this rule, an abstract is credited to the author whose name appears first in the by-line. **By action of our Council, abstracts will not henceforth be withdrawn from our proofs unless the asker sends ten dollars with his request.**

By exception, three copies of each abstract are requested for the Mexico meeting, so that one may be furnished to our Mexican hosts for translation, see page 5 of this Bulletin.

EPITOME OF THE 1955 TORONTO MEETING

(Personal names are those of invited speakers, except at the ends of lines where they are those of halls.)

Wednesday Morning

A. Apparatus of nuclear physics: Lorrain, Fulbright. McLennan 135.

B. Solid-state physics. McLennan 132.

C. Herzberg, Hartree, Kaempffer, Crawford. Wallberg.

D. Electron physics of upper atmosphere: Forsyth, Millman. Mechanical

Wednesday Afternoon

E. Robson, Gove, Duckworth, Thode. McLennan 135.

F. General physics. McLennan 106.

G. Magnetism. Wallberg.

H. Surface physics and electronic properties of solids: Reiss, Farnsworth. Mechanical.

Thursday Morning

J. Foster, Skinner, Katz, Russell. McLennan 135.

K. Cosmic rays: Demers, Rose, Korff. McLennan 132.

L. Radioactive substances; neutron physics. Wallberg.

M. Electron conduction in solids: Holstein, D. K. C. MacDonald. Mechanical.

Thursday Afternoon

N. Douglas, Hartman, Kerner, Volkoff. McLennan 135.

Q. Reactions of transmutation; post-deadline papers, if any. McLennan 132.

R. Electron emission and ejection phenomena: Hutson, Krusemeyer. Mechanical.

Thursday Evening at 7.00

Banquet of the American Physical Society. King Edward Hotel.

Friday Morning

S. General nuclear physics. McLennan 132.

T. Theoretical physics, I. Wallberg.

U. Semiconductors. McLennan 135.

V. Gaseous electronics and atomic physics, I; Massey. Mechanical.

Friday Afternoon

W. Theoretical physics, II. McLennan 132.

X. Cryogenics; Hallett, Reekie. McLennan 135.

Z. Gaseous electronics and atomic physics, II; Kerwin, A. D. MacDonald. Mechanical.

PROGRAMME

WEDNESDAY MORNING AT 10:00

McLennan 135

(L. G. ELLIOTT presiding)

Apparatus of Nuclear Physics

A1 Revised Yale Linear Electron Accelerator and Facilities.* W. G. WADEY AND H. L. SCHULTZ, *Yale University.*—The present linear electron accelerator at Yale as redesigned and rebuilt will be described together with the research facilities developed for use with it. The alignment procedures used and the operating characteristics in the most recent preliminary runs will be given.

* Supported by the U. S. Atomic Energy Commission.

A2. Electronic Instrumentation for the Yale Slow-Neutron Velocity Selector.* H. L. SCHULTZ AND W. G. WADEY, *Yale University.*—Electronic Instrumentation for the recording of neutron counts in the Yale slow-neutron velocity selector system will be discussed. Digital computing techniques are employed for time sorting and information storage. Serial adder and storage operations are possible due to the limited rate of data accumulation when the equipment is used under good-resolution conditions. One of the recording systems in use provides approximately five hundred, 2-μsec channels, each capable of storing over 1000 counts. The number of channels is limited essentially by the electrical length of the ultrasonic delay line used as the storage medium. The use of additional fast intermediate storage systems allows time expansion of any channel or group of channels for high-resolution work.

* Supported by the U. S. Atomic Energy Commission.

A3. Neutron Time-of-Flight Spectroscopy with a Linear Electron Accelerator.* T. F. GODLOVE AND J. G. CARVER, *Yale University.*—Using the Yale linear electron accelerator[1] beam with a gold x-ray producing target followed by a beryllium neutron producing target, preliminary runs have been made with a neutron time-of-flight spectrometer. The experimental arrangement will be described and measurements of the neutron capture spectrum of Tantalum reported. A value of 20.5 $\pm$0.4 μsec for the half-life of the isomeric state[2] in Ta^{181} has been obtained from γ rays following the x-ray flash from the accelerator. For the 4.30-ev resonance in Ta: 49$\pm$7 barn (ev)[3] from area analysis, Doppler corrected.

* Supported by the U. S. Atomic Energy Commission.
[1] H. L. Schultz and W. G. Wadey, Rev. Sci. Instr. **22**, 383 (1951).
[2] M. Goldhaber and R. D. Hill, Revs. Modern Phys. **24**, 224 (1952).

A4. Slow-Neutron Capture Resonances in Ta, W, and In.* J. G. CARVER AND T. F. GODLOVE, *Yale University.*—With the slow-neutron velocity selector described in the foregoing abstracts, neutron capture measurements have been made on Te, W, and In, using a modification of the method described by Meservey.[1] Capture studies were made on two different sample thicknesses for each element, and area analyses[2,3] were performed to obtain values of the level parameters for the resonances in Te and W between 0.6 and 20 ev, and for those in In between 0.6 and 10 ev. Results of these analyses will be presented showing that, while capture-γ-ray multiplicity and absolute detector efficiency need not be known, corrections for potential scattering are generally necessary.

* Supported by the U. S. Atomic Energy Commission.
[1] E. Meservey, Phys. Rev. **96**, 1006 (1954).
[2] Melkonian, Havens, and Rainwater, Phys. Rev. **92**, 702 (1953).
[3] D. J. Hughes (private communications).

A5. Ring-Focus Collection in Thin-Lens Nuclear Spectrometers. K. C. MANN, D. C. MILLEY, AND J. A. L. THOMPSON.—Some calculations have been made of electron trajectories in a conventional thin-lens, nuclear spectrometer for those cases where the radioactive source and the detector are not symmetrical about the thin-lens position. In this case, the performance characteristics of the spectrometer are greatly improved, provided the electrons are collected at the ring focus. One thin-lens instrument has been modified in this way, electron collection being effected by the use of thin flakes of anthracene mounted on a truncated cone of clear plastic, the crystals being placed in a ring at the focal position. The plastic cone acts as a light pipe to a photomultiplier mounted on the spectrometer axis. The method has proved to be very flexible, and offers a simple, inexpensive method of improvement of thin-lens spectrometer characteristics.

A6. Betatron Energy Control.* E. C. B. PEDERSON AND L. KATZ, *University of Saskatchewan.*—The detection of weak photonuclear levels using the betatron requires precise control of the peak Bremsstrahlung energy. A pickup coil in the electron orbit plane provides a voltage $V=k_1 d\phi/dt=k_2 dE/dt$, where ϕ is the total flux linking the orbit and E is the electron energy. An LRC integrator was built which is insensitive to changes in magnet excitation and line frequency. Integration of V using the LRC integrator gives a voltage $e=k_3 E$ which is compared with an adjustible preset voltage $e_1=k_3 E_1$ in a cathode-compensated feedback-diode circuit. When $e=e_1$, the electron orbit is caused to expand and strike a thin, heavy-element target, producing Bremsstrahlung with peak energy E_1. When $E_1=24$ Mev, a stability of $\pm$3 kev over a few hours and $\pm$20 kev over a few days is obtained.

* Supported by the National Research Council of Canada.

Invited Papers

A7. A Pressurized High-Frequency Cockcroft-Walton Accelerator. PAUL LORRAIN, *Université de Montréal.* (30 min.)

A8. The Variable-Energy Cyclotron at the University of Rochester. H. W. FULBRIGHT, *University of Rochester.* (30 min).

WEDNESDAY MORNING AT 10:00

McLennan 132

(K. G. McKAY presiding)

Various Topics in Solid-State Physics

B1. The Haeffner Effect in Mercury. G. G. EICHHOLZ, *Mines Branch, Department of Mines and Technical Surveys, Ottawa, Ontario.*—An effect resulting in isotopic concentration in pure liquid metals has been observed in mercury by Haeffner,[1] and in gallium by Nief and Roth.[2] The effect has been studied with tracer instead of mass spectroscopic techniques. Measurements have been carried out on mercury using mercury-203 as an indicator. Results will be presented for measurements at different temperatures, current densities, and tube dimensions.

[1] E. Haeffner, Nature **172**, 775 (1953).
[2] G. Nief and E. Roth, Compt. rend. **239**, 162 (1954).

B2. Some Crystal Growth Phenomena in High-Purity Lead. A. ROSENBERG AND W. C. WINEGARD.—In order to determine the mechanism of growth from the melt in metals, observations have been made on high-purity lead single crystals, solidified by the Chalmers' technique. An attempt has been made to relate the observed growth phenomena to the crystal orientation. The high-purity lead is obtained by zone refining, the effect of which is to remove impurities which can interfere with "normal" solidification through the creation of growth faults, such as corrugations and striations. Observations of growth are made on the upper free surface and on the solid-liquid interface which is revealed by accelerated decanting. To facilitate the observations on the upper surface, a simplified hot-stage microscope is employed which can follow the movement of the interface. The apparatus has been adapted to permit the simultaneous recording of the growth phenomena on motion picture film. Rapid grain boundary movement and associated transformations have been observed.

B3. Structure of Thin Evaporated Copper Films by Total Reflection of X-Rays.* L. G. PARRATT, *Cornell University.*—The x-ray total reflection method of studying certain structural properties of the surfaces of solids has been applied to thin evaporated copper films deposited on a glass substrate at room temperature. Films of average thickness about 25 to 1000 A have been studied with the x-ray wavelength 1.392 A. The reflection curves disagree significantly in several respects with the theoretical curves based on a film model of homogeneous lamina. A better model may be one in which the copper (with some oxide) is present in aggregates of such shape that a very low average dispersion density exists close to the glass substrate. As the thickness of the film increases, the copper aggregates may "bridge over" at some 40 A or so above the substrate to form a more or less continuous but porous film. Such a model features a "reflection trap." This work is exploratory in the sense that no satisfactory attempt was made to control the physical and chemical variables involved in the preparation and treatment of the surfaces. But, under controlled conditions, the method promises interesting information about surface structure.

* Supported in part by the U. S. Air Force through the Office of Scientific Research and Development Command.

B4. Effect of a Centrifugal Field on the Rate of Diffusion in Metals.* J. J. CONNELLY, JR.,† O. R. HARRIS, AND J. W. BEAMS, *University of Virginia.*—Three successive layers of silver were electrodeposited upon the cylindrical surface of a 0.55-cm diameter steel rotor. The inner layer (7×10^{-5} cm thick) and the outer layer (14×10^{-5} cm thick) consisted of ordinary silver, while the middle layer contained silver enriched with the radioactive isotope Ag^{110}. The rotor was magnetically suspended and spun for long periods of time in an evacuated chamber, the temperature of which could be held constant. The radial movement of the Ag^{110} was determined by counting the beta particles emerging through the periphery of the rotor by a scintillation crystal, photomultiplier, and pulse-height analyzer circuit as a function of time. The results show that the Ag^{110} migrated toward the periphery faster with the rotor spinning (4000 to 10 000 rps) than when it was not spinning. The temperature was 300°.

* Supported by the Office of Ordnance Research.
† U. S. Navy Postgraduate student.

B5. Theory of Slip-Band Formation. R. B. GREEN, *Baker & Company Research Laboratory.*—In letters submitted to *The Physical Review* the writer introduced a new defect, the screwedge dislocation, and showed that slip which cuts screw-edges in face centered cubic metals must produce c.p.h. type stacking faults, and when it proceeds more than the distance between screwedges must produce Frank-Read sources, "head-on" stacking faults of high energy (cracks), or other c.p.h. stacking faults, depending on the geometry of the particular interacting screwedges. The approximate distance between screwedges, and so amount of slip required to produce cracks or Frank-Read sources, is also the length of Frank-Read sources similarly produced earlier. Using $\tau^*=Gb/L$ and G/τ^* of 1000 for worked metal, a length of 600 lattice units is found. Such slip will proceed until it produces a "head-on" fault (crack), being halted when kinetic energy of slip goes to form the "head-on" fault. The "head-on" fault length might reasonably be one tenth the slip length. If the lattice strain about a "head-on" fault were effective within one fault dimension in reducing the probability of slip on parallel planes, a slip-band structure would be produced as observed, slips about 600 lattice units long spaced 60 units apart.

B6. Initial Stages of Oxidation of Nickel. URSULA M. MARTIUS, *Ontario Research Foundation.*—Under certain experimental conditions it is possible to observe the very beginning of oxidation of a metal surface.[1–5] Prior to the formation of a continuous oxide layer, small oxide crystals nucleate on the metal surface. Their shape, size, and number per unit area was found to depend strongly on the crystallographic orientation of the underlying metal. Microscopic observations of the initial oxidation of high-purity nickel are presented. The oxidation at grain boundaries is discussed in detail and the tentative theoretical explanation of the observed phenomenon is given.

[1] J. Bardolle and J. Benard, Rev. de Met. **49**, 613–22 (1952).
[2] J. Bardolle, Rev. de Met. **51**, 835 (1954).
[3] E. A. Gulbransen and W. R. McMillan, J. Appl. Phys. **24**, 1416 (A) (1953).
[4] W. W. Harris and F. L. Ball, J. Appl. Phys. **24**, 1416 (A) (1953).
[5] U. M. Martius, Can. J. Phys. (to be published).

B7. Location of the Hydrogen Atoms in the Unit Cell of Portlandite $[Ca(OH)_2]$.* H. E. PETCH, *Crystallographic Laboratory, Cavendish Laboratory, and McMaster University.*—On the basis of the complex infrared spectrum obtained with brucite $[Mg(OH)_2]$, Mara and Sutherland[1] have suggested that the unit cell must be much larger than that deduced from x-ray data[2] and that the positions of the hydrogen atoms predicted by Bernal and Megaw[3] are incorrect. The isomor-

phous potrlandite [$Ca(OH)_2$] also has a complex infrared absorption spectrum[4] closely analogous to that obtained for brucite, leading one to expect similar effects in the two structures. A re-examination of the crystal structure of brucite and portlandite by means of x-rays has been undertaken. No evidence has been found for a larger unit cell in either brucite or portlandite.[4] More recent work on the portlandite in which a Geiger-counter x-ray diffractometer and the technique of the $(F_o - F_c)$ synthesis have been used, has resulted in more accurate atomic parameters for the oxygen atoms and strong evidence supporting the hydrogen positions predicted by Bernal and Megaw, in contradiction to the suggestion made by Mara and Sutherland.

* Supported by the National Research Council of Canada and the Royal Society of Canada.

[1] R. T. Mara and G. B. B. M. Sutherland, J. Opt. Soc. Am. **43**, 1100 (1953).
[2] G. Aminoff, Geol. Fören. i Stockholm Förh. **41**, 407 (1919).
[3] J. D. Bernal and H. D. Megaw, Proc. Roy. Soc. (London) **A151**, 384 (1935).
[4] H. E. Petch and H. D. Megaw, J. Opt. Soc. Am. **44**, 744 (1954).

B8. Color Centers in KI at Liquid Helium Temperatures. HERBERT N. HERSH, *Zenith Radio Corporation.*—Absorption spectra of colored and x-rayed KI have been obtained from liquid-helium temperatures to room temperature. The following observations have been made: (1) Crystals x-rayed at LHT contain a very much smaller number of *F*-centers than ones similarly irradiated at room temperature; this behavior of * KI is in contradistinction to the relatively small temperature effects reported for NaCl, KCl, KBr. (2) Absorption bands are concomitantly produced at 800, 404, and 335 mμ. (3) The shifting towards the uv of the tail of the first-fundamental absorption band at low temperatures has allowed observation to be made of 2 bands on the low-energy tail of the fundamental band in the uncolored crystal. (4) A narrow, pronounced band at 281 mμ in the uncolored crystals appears to be identical with a band at 287 mμ found by Uchida and Nakai in some of their crystals.

B9. Experimentally Determined Configuration Coordinate Curves for *F*-Centers in Alkali-Halide Crystals. G. A. RUSSELL AND C. C. KLICK, *U. S. Naval Research Laboratory.*—Configuration coordinate curves for *F*-centers in KCL, KBr, KI, and NaCl have been established from experimental observations. Use has been made of the change in absorption band width of the *F*-band with temperature, the position of the absorption maximum at low temperature and the peak of the emission band of the *F*-center luminescence.[1] The widths of the emission bands at half-maximum predicted by the configuration coordinate curves are in good agreement with the results reported by Botden, van Doorn, and Haven.[1] The low efficiency of *F*-center luminescence[1,2] can be explained in terms of these curves using the criterion for luminescence in simple centers which has been proposed by Dexter, Klick, and Russell.[3]

[1] Botden, van Doorn, and Haven, Philips Research Rept. **9**, 469 [1954).
[2] C. C. Klick, Phys. Rev. **94**, 1541 (1954).
[3] Dexter, Klick, and Russell (to be published).

B10. Some Optical Measurements on Additively Colored MgO Single Crystals.* BERNARD V. HAXBY, *University of Minnesota.*—The build-up of the optical absorption bands characteristic of excess oxygen in MgO single crystals has been measured as a function of temperature with constant oxygen concentration over the crystals during heat treatment. The growth of the band maxima has been found to satisfy a diffusion mechanism, and the temperature dependence of the diffusion coefficient is described by an activation energy of 3.4 electronvolts. The temperature dependence of the heights of the band maxima at saturation show a possible indication that energy is gained in the formation of the centers responsible for the optical absorption. Some results in the additive coloration with magnesium and of an experimental determination of the absolute concentration of excess magnesium in MgO crystals will also be presented.

* Supported by The U. S. Army Signal Corps.

B11. Anisotropic Color Centers in α Quartz. ALVIN J. COHEN, *Mellon Institute.*—New color centers are reported in amethyst at 225, 266, and 360 mμ. The 360-mμ center is anisotropic, and its overlap with the well-known 540 mμ color center may account for the anisotropy reported for the latter.[1] The color center at 460 mμ in naturally colorless or bleached smoky quartz after *x*-irradiation has been shown by the author to be anisotropic.[2] What is apparently the same center has been observed in Brush synthetic quartz by Arnold[3] and is now found to be anisotropic with a maximum at 460 mμ for the extraordinary ray and at 485 mμ for the ordinary ray. The optical densities of both anisotropic centers studied were greater for the extraordinary ray in qualitative agreement with earlier work[4] on smoky quartz.

[1] S. Pancharatnam, Proc. Indian Acad. Sci. **40A**, 196 (1954).
[2] A. J. Cohen, J. Chem. Phys. **23**, 589 (1955).
[3] G. W. Arnold, Jr., J. Chem. Phys. **22**, 1259 (1954).
[4] N. E. Vedeneeva and E. S. Rudnitskaya, Doklady Akad Nauk. S.S.S.R. **87**, 361 (1952); Chem. Abstracts **47**, 6259 (1953).

B12. The Electrical Resistance Properties and Structure of Thin Evaporated Silver Films. R. A. AZIZ AND G. D. SCOTT, *University of Toronto.*—The spontaneous ageing of thin films of silver was studied by following electrical resistance variations with time immediately after deposition in vacuum. In one series of experiments, films, all deposited in a fixed time of 100 seconds and with initial resistances from 170 000Ω to 20Ω, were investigated. The resistance of some films rose rapidly with time, while in others, it dropped rapidly and in still others, the ageing was less pronounced. In a second series, eight films were formed, all with an equal initial resistance (5000Ω) but deposited in different times. The rate of decrease in resistance is greater as the rate of deposition increases. The limiting value of resistance depends on the time of deposition. A possible qualitative explanation of the results on the basis of distortion decay and film aggregation is proposed. The structure of thin silver films <200 a.u. is found to be influenced by the atomic velocity provided the rate of deposition is not high. Two independent experiments are described in which the velocity is reduced in two different ways. Electron micrographs and resistivity-thickness curves are given. The effect is explained on the basis that decreased atomic velocity reduces the energy available for migration on the surface.

WEDNESDAY MORNING AT 10:00

Wallberg Building

(E. P. WIGNER presiding)

Invited Papers

C1. Lamb Shifts in He+ and He. G. HERZBERG, *National Research Council, Canada.* (30 min.)

C2. Interpolation of Atomic Wave Functions and Fields. D. R. HARTREE, *Cambridge University.* (30 min.)

C3. Atomic Wave Functions, with Exchange, for Some Atoms of the First Long Period. D. R. HARTREE, *Cambridge University.* (15 min.)

C4. Models of Elementary Particles. F. A. KAEMPFFER, *University of British Columbia.* (30 min.)

C5. Nuclear Configurations from Isotope Shifts. M. F. CRAWFORD, *University of Toronto.* (30 min.)

WEDNESDAY MORNING AT 10:00

Mechanical Building

(TAO-YU WU presiding)

Electron Physics of the Upper Atmosphere

Invited Papers

(D1 at the beginning, D2 after D6)

D1. Scattering of Radio Waves from Aurora and Meteors. P. A. FORSYTH, *Defence Research Telecommunications Establishment.* (25 min.)

D2. Excitation and Ionization Produced by Meteors. P. M. MILLMAN, *National Research Council (Canada).* (25 min.)

Contributed Papers

D3. Motions of Auroral Light Forms. J. H. MECK, *University of Saskatchewan.*—All-sky photographs are being made regularly each night at Saskatoon. These consist of successive two-minute exposures made with 16-mm panchromatic film throughout the dark hours. The photographs give a complete record of the brighter auroral forms and demonstrate their variability. A 16-mm film is presented in which the motions of the aurora are speeded up almost 2000 times. Several interesting nights during the past year are shown. The movement of the aurora is discussed and compared with the disturbance vector of the earth's magnetic field.

D4. Infrared Spectrum of the Night Sky near 10 000 A.* A. VALLANCE JONES, *University of Saskatchewan.*—The infrared spectrum of the night sky has been obtained using Kodak 1Z(2) plates. Numerous lines were obtained of which all are identified as arising from the (5,2), (4,1), (3,0), (9,5), and (8,4) OH rotation-vibration bands. These results are compared with spectra obtained in the same region by other techniques.

* Supported by the Geophysics Research Division of the U. S. Air Force Cambridge Research Center.

D5. Seasonal Intensity Variation of Twilight Sodium Emission.* D. M. HUNTEN, *University of Saskatchewan.*—The maximum intensity has been measured on about 100 occasions over two years with a photoelectric spectrometer. The two years agree very well, showing a minimum of about 6×10^7 quanta/cm^2 sec sterad at the end of June and a maximum from January to March with intensity fluctuating between 2 and 4×10^8 quanta/cm^2 sec sterad. The variation of intensity is presumably the result of a variation in the number of free sodium atoms per cm^2 between 6 and 40×10^9. No fully satisfactory explanation is known. Some of the possibilities will be discussed.

* Supported by the Geophysics Research Division of the U. S. Air Force Cambridge Research Center.

D6. Ozone Measurements over Edmonton (Lat. N. 53°34', Long. W. 113°31') 1951 to 1954. E. H. GOWAN, *University of Alberta.*—There are now available atompsheric ozone measurements in Edmonton from 1951 through 1954. The ten-day means have been computed, and the four-year average of these means is compared with similar data taken in Oxford, England, to show effects of difference in geographic location at nearly the same latitude. Some of the day-to-day ozone results have been compared with upper air data, which is also available for Edmonton. The usual significant negative correlations of ozone amount with height of 100-, 200-, 300-, and 500-millibar levels, and tropopause, is evident, with the strongest correlation occurring for the 300-mb level. The mean height and the height distribution has been measured by the umkehr curve method on a few days during the summer of 1953. Night measurements near the time of full moon were successful from September, 1954, up to four days either side of full moon, with zenith angles of from 30° to 60°. It may be possible to observe with the moon lower in the sky, by pushing the voltage on the photomultiplier a bit higher.

D7. Diurnal Variations in the Rate of Meteor Detection by Forward-Scattering. C. O. HINES, P. A. FORSYTH, AND E. L. VOGAN, *Defence Research Board.*—By combining Eshleman's formula for forward-scattering from meteor trails, and the theory of meteor trail formation, it is possible to determine the relative "observability" of meteor trails as a function of their radiant positions. This in turn provides a basis for predicting diurnal variations in the detection rate of meteors, both for meteor showers and for the random background of sporadic meteors. The theoretical predictions agree fairly well with the observed variations in both instances. By proper application, the theory should prove useful in resolving minor showers from the random background, and in locating the corresponding radiant position.

D8. VHF and UHF Propagation in Central Canada. D. R. HAY AND R. C. LANGILLE, *Defence Research Board.*—Since 1953, the Radio Physics Laboratory has carried out amplitude measurements on VHF and UHF signals, propagated through the troposphere to ranges up to 260 miles. These measurements have been made over rolling terrain during winter and summer between antennas whose height above ground was less than 100 feet but greater than one wavelength. A brief summary of the results obtained in this experiment will show the deep fading in signal amplitude, noise signals emitted by a thunderstorm at VHF and UHF, and a comparison between measured signals and the signals predicted by diffraction theory and scatter theory.

D9. Radio Star Scintillations and the Ionosphere. T. R. HARTZ, *Defence Research Board.*—The observed intensity at the surface of the earth of radiation at a frequency of 50 mc/s from a "radio star" has been studied. A relationship is shown to exist between the fluctuations, or scintillations, in this observed radiation intensity and the angle of its incidence on the 400-Km level of the earth's ionosphere. The occurrence of these scintillations is compared to other ionospheric phenomena as determined by vertical soundings from the earth. The probable cause of the fluctuations has been localized to a source in the high-ionospheric regions.

D10. Pictures of Gas-Streams at Low-Gas Density Taken by Means of Electrons. BERTHOLD W. SCHUMACHER.* *High Voltage Laboratory of the Max Planck Gesellschaft, Hechingen, Germany.*—It is possible to measure the density of a gas by means of the attenuation of an electron beam, passing through the gas. Even at low-gas densities, a high-attenuation coefficient may be obtained by using low-energy electrons. With a suitable optimum electron energy it is possible to obtain shadowgraphs[1] of a field of variable gas density. These shadowgraphs register with considerable sensitivity small differences in gas density and show a large resolution of details. Data showing the sensitivity have been obtained experimentally and will be discussed in detail. Especially in the low-density range where the optical interferometer fails, the electron shadowgraphs may become a useful tool of aerodynamics.

* Now at the Ontario Research Foundation, Toronto, Ontario.
[1] B. Schumacher, Ann. Physik **13**, 404–420 (1953).

WEDNESDAY AFTERNOON AT 2:00

McLennan 135

(L. KERWIN presiding)

Invited Papers

E1. An Experiment on the Angular Correlation in the Beta Decay of the Neutron. J. M. ROBSON, *Chalk River.* (30 min.)

E2. Some Measurements of Properties of Light Nuclei, Using the Chalk River Accelerator. H. E. GOVE, *Chalk River.* (30 min.)

E3. Present Status of Atomic-Mass Measurements. H. E. DUCKWORTH, *McMaster University.* (30 min.)

E4. Abnormal Fission Yields and Nuclear Shell Structure. H. G. THODE, *McMaster University.* (30 min.)

WEDNESDAY AFTERNOON AT 2:00

McLennan 106

(W. H. WATSON presiding)

General Physics

F1. An Experimental Investigation of the Diffraction of Electromagnetic Waves by a Dominating Ridge. J. H. CRYSDALE, J. W. B. DAY, AND W. S. COOK, *Radio Physics Laboratory.*—The diffraction fields produced at 173.493 and 1785 Mc/s behind a dominating ridge north of Ottawa have been investigated experimentally with horizontally and vertically polarized radiation. Measurements were made during both winter and summer in order to evaluate the effect of changing ground and foliage conditions. The determination of angles of arrival and the assessment of the modifications of the fields due to the terrain between the experimental sites and the obstruction were facilitated by: (1) The mounting of the antennas on path testing towers at the transmitting site south of the ridge and at the receiving sites north of the ridge. This

permitted a considerable range of variation of antenna height, and azimuth and elevation angles. (2) The use of a monitoring station on the top of the ridge from which line-of-sight conditions existed to the transmitting site and the receiving sites. The experimental arrangement is described briefly, and the results are presented, discussed, and compared with the predictions of classical knife-edge and more exact theories.

F2. An Investigation of Slot Radiators in Rectangular Metal Plates. D. G. FROOD AND J. R. WAIT.—The radiation from slots cut in conducting surfaces of limited extent is discussed. Equatorial plane patterns of an axial half-wave slot in a rectangular metal plate are measured at *X*-band frequencies for plate widths which vary between 1 and 45 wavelengths. The experimental results compared favourably with the calculated patterns on the assumption that the plate can be represented by a thin elliptic cylinder of infinite length. It is observed that if the plate length is equal to or greater than its width the pattern is within a few percent of the corresponding theoretical pattern for a plate of infinite length. The admittances of the slots were also measured and compared with theoretical values of conductances. The agreement is seen to be quite good.

F3. A Parallel-Plate Transmission Line. JOHN E. KEYS, *Radio Physics Laboratory.*—A parallel-plate transmission line operating at a wavelength of 10 cm has been constructed at the Radio Physics Laboratory for measuring the radiation and scattering patterns of models. A description will be given of this instrument and several problems which arose in its development. To check its accuracy, scattering patterns of metal cylinders were taken and checked against known theoretical results. In its present form, the line proves to be accurate to ± 2 percent in amplitude measurements and $\pm 3°$ in measurements of phase.

F4. Scattering of Electromagnetic Waves by Coaxial Cylinders. ALBERT W. ADEY. *Defence Research Board.*—A scattering system comprising two coaxial, dielectric, circular cylinders has been studied theoretically and experimentally. Calculations have been made of the forward- and back-scattered fields for several combinations of inner and outer radii. It has been found that, by covering a metal cylinder with a coaxial dielectric shield, it is possible to eliminate to some extent the deep near field shadow. Experimental results obtained at a wavelength of 3.275 cm using a parallel-plate transmission line are in good agreement with calculations.

F5. Infrared Absorption in Gaseous, Liquid, and Solid Carbon Dioxide Induced by Intermolecular Forces. V. GAIZAUSKAS AND H. L. WELSH, *University of Toronto.*—The ν_1 infrared absorption band of carbon dioxide, induced by intermolecular forces in the compressed gas, shows a large deviation from square-law variation with density. The deviation is explained as a pressure effect on the rate of change of polarizability and is related to the variation of Raman intensity and refractive index with density. The ν_1 band observed in thick crystals is totally different from that observed in the gas and liquid, and can be interpreted as sum and difference tones of the molecular frequencies with the vibrational frequencies of the crystal lattice. In the gas and liquid, the induced absorption is caused by asymmetric distortion of the molecule in collisions. In the crystal, in which each molecule is a center of symmetry of the lattice and the molecular rotation is hindered, asymmetric distortion can be produced only as a result of the lattice vibrations; therefore, only sum and differences tones of the molecular frequencies with the lattice frequencies occur in induced absorption.

F6. Infrared Absorption of Liquid and Solid Hydrogen and Its Dependence on the *Ortho-Para* Ratio. ELIZABETH J. ALLIN, W. F. J. HARE, AND H. L. WELSH, *University of Toronto.*—The fundamental infrared absorption of liquid and solid hydrogen has been studied from 22°K to 4.2°K with *ortho-para* ratios varying from 0 to 0.75. The absorption consists of three superimposed patterns of Q, $S(0)$, and $S(1)$ lines. One pattern consists of broad lines, interpreted as absorption induced by distortion due to overlap forces; in this case the vibrational frequency is modulated both by the lattice vibrations and the rotation of the molecule. A second pattern of strong sharp lines is probably due to the quadrupole interaction of the absorbing molecule with its first neighbors in the lattice. The third pattern, of weak sharp lines, arises from the quadrupole interaction of the absorbing molecule with its more distant neighbors; the frequencies in this case correspond most closely to those which would be obtained in Raman scattering. The complex dependence of the intensities of the various components on the *ortho-para* ratio will be discussed.

F7. Automatic Computation of the Electronic Wave Functions of Molecules.* R. C. SAHNI, *University of Western Ontario.*—A programme for the automatic computation of electronic wave functions of molecules using molecular integrals as the external data has been constructed for an electronic computer. Using this program a number of wave functions of the ground, ionic, and excited states of N_2 have been calculated at various internuclear distances. Transition probabilities, ionization potentials, molecular orbitals, and energy values which have been calculated, and a number of other properties of the ground, ionic, and excited states of N_2 are discussed.

* This work is supported by the Air Force Cambridge Research Center.

F8. Scintillation Spectrometry of X-rays from a Be-Window Tube.* P. K. S. WANG, R. J. RARIDON, AND MARVIN TIDWELL, *Vanderbilt University.*—The energy spectrum of a Be-window x-ray tube operating at 50 PKV was obtained using an NaI(Tl) scintillation spectrometer. When a crystal with a 25-mil Al window was used the measured continuum agreed fairly well with Kramers' Theory.[1] However, when a crystal with a ¼-mil Al window was used, a high-intensity peak superimposed on the long wavelength end of the continuum was observed. Absorption measurements showed the energy of the peak to be comparable to the energy of the L x-rays of the tungsten target. When this peak was effectively filtered out, an attenuation curve taken with Al absorbers gave, by Laplace transformation, a spectrum which agreed with the bremsstrahlung continuum obtained by Emigh and Megill.[2] The contribution of the characteristic L-radiations to the total intensity of the beam amounted to 35 percent.

* Work partially supported by a sponsored project of the U. S. Atomic Energy Commission. Preliminary results were reported at the Gainesville meeting of the Southeastern Section of the American Physical Society, April 7, 1955.

[1] H. A. Kramers, Phil. Mag. **46**, 836 (1923).

[2] C. R. Emigh and L. R. Megill, Non-Destructive Testing **11**, 30 (1953).

F9. Currents and Water Masses in Lake Huron. D. V. ANDERSON, *Department of Lands and Forests,* J. C. AYERS, *Cornell University,* AND D. C. CHANDLER AND G. H. LAUFF, *University of Michigan.*—In the summer of 1954 three synoptic surveys were made of the physical and chemical structure of the waters of Lake Huron to trace their seasonal variations and their movements. Bathythermograms were made, surface currents measured, and water samples taken at several depths, and other observations were made on the same days from eleven boats which followed a network of courses over the lake. Some of the results of the work are presented to show the distribution of water temperature, the concentrations of calcium, magnesium, and silicon, and the probable pattern of currents in the lake.

F10. Transfer Rate Measurements in a Hydrodynamic System Containing a Nonuniformly Mixing Compartment.* GERALD A. WRENSHALL AND HARRY SCHACHTER, *University of Toronto.*—The mathematical basis developed by Sheppard and Householder[1] for the tracer measurement of transfer rates in uniformly mixing constrained steady-state systems of compartments has been extended. A basis for measurements of transfer rates between compartments using a single tracer substance in constrained but open systems containing nonuniformly mixing compartments will be presented. The revised basis does not entail assumptions concerning dynamic equilibrium. The applicability of this development has been tested using techniques described elsewhere[2] by comparing direct and tracer-measured transfer rates in a hydrodynamic systems of compartments, in one of which uniform-mixing did not occur. Direct and tracer-measured transfer rates for this compartment were found to agree to within 4 percent.

* Work supported by the National Research Council (Canada), and the Banting Research Foundation.
[1] Sheppard and Householder, J. Appl. Phys. 22, 510 (1951).
[2] L. C. Lax and G. A. Wrenshall, Nucleonics 11, 18 (1953).

F11. Simultaneous Rates of Phosphorus Transfer between Fifteen Compartments within the Rat.* LOUIS C. LAX AND GERALD A. WRENSHALL, *University of Toronto.*—A mathematical basis for the tracer measurement of rates in systems containing compartments in which uniform mixing can not be assumed to occur[1] has been applied to the total phosphorus contained in the normal fasting male Wistar rat, weighing 200 gm. Using P^{32} as a tracer, and assuming that the trichloroacetic acid-soluble phosphorus of blood plasma represents a part of the central mammillary[2] phosphorus compartment in the rat, rates of phosphorus transfer from this compartment to fifteen peripheral mammillary compartments have been calculated. Expressed as μg/min, these are: bones and teeth 152, skeletal muscle 55.4, liver 42.0, urine 12.3, skin 10.8, withdrawn blood cells 4.52, kidneys 4.50, nonvisceral fat 2.99, gastrointestinal tract 2.38, lungs 1.89, testicles 1.71, spleen 1.68, heart 1.47, brain 0.23, remainder 1.79. The independently calculated total rate of phosphorus transfer from the central compartment to the peripheral ones (303) was found to correspond closely with the sum of the calculated transfer rates from the peripheral compartments to the central one (296). The method of analysis also provides values for the amount of phosphorus within each compartment, thus making available values for the average time a phosphorus atom remains in each compartment.

* Supported by the National Research Council (Canada) and the Banting Research Foundation.
[1] Wrenshall and Schachter, Bull. Am. Phys. Soc. 30, No. 4, 14 (1955).
[2] Sheppard and Householder, J. Appl. Phys. 22, 510 (1951).

F12. Specific Interaction between Identical Molecule Pairs. HERBERT JEHLE, J. M. YOS, AND W. L. BADE, *University of Nebraska.*—A new approach has been made to compare the interaction free energy of a pair of identical molecules with that of a nonidentical pair, due to polarizability-polarizability interaction of oscillator sets representing the molecules. For such an oscillator set model it is shown that two identical macromolecules imbedded in a homogeneous medium will always associate to become a close neighbor pair, as that provides for the lowest free energy.

F13. A Calorimetric Method for the Direct Determination of the Energy Locally Absorbed in an Irradiated Material. J. P. BERNIER, H. E. JOHNS, AND D. V. CORMACK, *University of Saskatchewan.*—The relation between the energy absorbed per unit mass at a point in a solid material and the ionization per unit mass in an infinitesimal gas-filled cavity situated at that point is given by the Bragg-Gray formula, $E_m = JmW\rho_m$, where W is the mean energy expended in the production of an ion pair in the gas and ρ_m the mass stopping power of the solid relative to the gas. The present paper describes a method for measuring independently E_m and J_m. From these, the product $W\rho_m$ can be determined for different combinations of gases and solid materials. Assuming the ratio of the mass stopping power of carbon to air to be $\rho_m = 1.003$, we obtain 34.2 ev/ion pair for air, for electrons set in motion by cobalt 60 gamma rays. Results will be presented for other materials.

WEDNESDAY AFTERNOON AT 2:00

Wallberg Building

(J. E. GOLDMAN presiding)

Magnetism

G1. Magnetic Susceptibility of Ti and Substitutional Ti Alloys. J. M. DENNEY,* *California institute of Technology.*—The magnetic susceptibility of Ti and of solid solution alloys of Al, Ga, and Ag in Ti has been determined by the Faraday method with field dependent corrections ascertained by the method of Honda and Owen. Specimen impurities determined by spectrographic analysis were less than 0.01 percent. The field dependence of the susceptibility, $\partial\chi/\partial(1/H)$, was $\sim 10^{-5}$ esu-oersted. A gram-susceptibility of $3.31\times10^{-6}(\pm0.02\times10^{-6})$ esu was found for Ti at 296°K with a positive, approximately linear, $\partial\chi/\partial T$ of 1.2×10^{-9} esu/°K in agreement with the results of Squire and Kaufman.[1] Susceptibility-concentration coefficients at 296°K for Ti solid solutions up to 5 atmos. percent Al, Ga, or Ag were found to be small: -0.023, -0.031, -0.059×10^{-6} esu/atmos percent, respectively; however, the solute additions caused large changes in lattice parameters and other physical properties. The relative independence of χ with lattice spacing in the alloys and other considerations suggest that the major contribution to χ is due to interaction of d-electrons in contrast to a previously suggested explanation.[1] The $\chi(T)$ and other properties can be interpreted on the basis of a two-band model in which one band is characterized by an antiferromagnetic exchange. More direct evidence to substantiate or disprove this view is desirable.

* Now at the General Electric Research Laboratory, Schenectady, New York.
[1] C. F. Squire, and A. R. Kaufman, J. Chem. Phys. 9, 673 (1941).

G2. Magnetic Susceptibility of Sodium. R. BOWERS, *Westinghouse Research Laboratories.*—The susceptibility of sodium has been measured from room temperature down to 55°K using a Gouy balance. The susceptibility at room temperature was found to be $(0.70\pm0.03)\times10^{-6}$ cgs mass units. The renewed interest in the susceptibility of the alkali metals arises from recent calculations of the paramagnetic contribution of the conduction electrons,[1,2] as well as the possibility of measuring this contribution directly.[3] An analysis of our

data on the basis of these calculations leads to a rather small diamagnetic contribution from the conduction electrons, less than one-fourth of the Landau free electron value. No abnormal behavior was found in the susceptibility between 77°K and 55°K, where the Knight shift shows signs of being anomalous.[4] Hence, within this limited temperature range, the behavior of the nuclear resonance is not due to a change in the density of states.

[1] D. Pines, Phys. Rev. **95**, 1090 (1954).
[2] T. Kjeldaas and W. Kohn, Bull. Am. Phys. Soc. **30**, No. 3 (1955).
[3] C. P. Slichter, Phys. Rev. **95**, 1089 (1954).
[4] W. D. Knight, Phys. Rev. **96**, 861 (1954).

G3. Magnetic Susceptibility of Metallic Lithium. EMERSON WILLIAM PUGH AND J. E. GOLDMAN, *Carnegie Institute of Technology.*—Schumacher, Carver, and Slichter[1] have recently measured the paramagnetic part of the magnetic susceptibility of metallic lithium by the spin resonance method. Using this data, plus the diamagnetic contribution of the core electrons and an experimental value for the total susceptibility, an estimate of the diamagnetism of the conduction electrons can be made. Large discrepancies in existing values for total susceptibility led the authors to remeasure the value at room temperature, using the Gouy method on two samples[2] of different purity. One sample was 99.9 percent pure while the second was commercial grade lithium with about 0.6 percent Na. Both samples were approximately 0.89 cm in diameter by 13 cm in length and measurements were made in fields ranging up to 17 000 gauss. The total susceptibility thus obtained is $2.04\pm0.07\times10^{-6}$ cgs volume units for the pure sample and $1.99\pm0.07\times10^{-6}$ for the other. The results will be compared to earlier measurements of this quantity and an upper limit placed on the conduction electron diamagnetism.

[1] Schumacher, Carver, and Slichter, Phys. Rev. **95**, 1089 (1954).
[2] Kindly supplied by the Lithium Corporation of America.

G4. Magnetic Susceptibility of UO_2 from 2°K to 300°K. ANTHONY ARROTT AND J. E. GOLDMAN, *Carnegie Institute of Technology.*—A specific anomaly has been observed in UO_2 at 29°K[1] which is believed to be indicative of a transition to an antiferromagnetic state. However, Trzebiatowski and Selwood[2] have measured the susceptibility at 20°K and found no evidence for antiferromagnetism. Using a sample provided by O. C. Simpson of Argonne National Laboratory, we have investigated the magnetic susceptibility from 2°K to 300°K. The results are indicative of antiferromagnetism. The susceptibility deviates from Curie-Weiss behavior below 50°K. It reaches a maximum between 33°K and 28°K and then drops to 0.9 of its maximum value at 25°K. From 25°K to 2°K the susceptibility is temperature independent. The constants in the Curie-Weiss law when compared with the results of Dawson and Lister[3] indicates a deficiency of U in our sample of the order of 7 percent. Measurements on samples having slightly different stoichiometry will be discussed.

[1] Jones, Gordon, and Long, J. Chem. Phys. **20**, 695 (1952).
[2] W. Trzebiatowski and P. W. Selwood, J. Am. Chem. Soc. **72**, 4504 (1952).
[3] Dawson and Lister, J. Chem. Soc. **1950**, 2181 (1950).

G5. Crystal Structure of Gadolinium Orthoferrite, $GdFeO_3$.* S. GELLER, *Bell Telephone Laboratories, Inc.*—The crystal structure of gadolinium orthoferrite, $GdFeO_3$, has been determined from single crystal x-ray data. There are four $GdFeO_3$ distorted perovskite units in the orthorhombic cell with lattice constants $a=5.34$, $b=5.62$, $c=7.67\pm0.01$ A. The structure is solved on the basis that the most probable space group is D_{2h}^{16}-Pbnm. However, although the atomic coordinates lead to very good agreement between calculated and observed reflection amplitudes, there are at least very slight deviations from the centrosymmetric space group because the iron sublattices are imperfectly antiferromagnetic. Compounds definitely isomorphous with $GdFeO_3$ are the orthoferrites of Nd^{3+}, Sm^{3+}, Eu^{3+}, Pr^{3+}, La^{3+}, Y^{3+}, $YAlO_3$, and $YCrO_3$. Probably most of the perovskite-like crystals reported by Naray-Szabo[1] and Megaw[2] as monoclinic are isomorphous with $GdFeO_3$.

* This work was stimulated by Professor L. Néel, Dr. B. T. Matthias, and Dr. M. A. Gilleo. The successful solution of this problem is in large measure due to the availability of sizable single crystals grown by Mr. J. P. Remeika.
[1] St. v. Naray-Szabo, Publ. Univ. Tech. Sci., Budapest **1**, 30–41 (1947).
[2] H. D. Megaw, Proc. Phys. Soc. (London) **58**, 133 (1946).

G6. Magnetic Properties of a Gadolinium Orthoferrite Crystal. M. A. GILLEO, *Bell Telephone Laboratories, Inc.*—In a crystal gadolinium orthoferrite,[1] $GdFeO_3$, the susceptibility χ and the parasitic ferromagnetic moment σ_0 are anisotropic, as is expected in an orthorhombic structure. The maximum and minimum of both χ and σ_0 change direction with change of temperature. A common direction for χ min and σ_0 max is expected in the absence of Gd according to the hypothesis that σ_0 arises from incomplete compensation of two antiferromagnetic Fe sublattices. However, the observed directions of χ min and σ_0 max do not coincide. Over the temperature range 77 to 300°K χ can be almost wholly attributed to Gd. The magnitude of σ_0 at 77°K is about 1 percent of the available σ(Fe) and is only a little less at 300°K.

[1] Work on $GdFeO_3$ in ceramic form has been carried out by Néel and co-workers [Pauthenet and Blum, Compt. rend. **239**, 33 (1954)].

G7. Magnetic Measurements on a Single Microscopic Particle. A. H. MORRISH AND S. P. YU, *University of Minnesota.*—A quartz torsion balance has been constructed, which permits measurements to be made on an individual magnetic particle of about 1 micron diameter (mass $\sim10^{-12}$ gram). The suspension fiber in the instrument was between 0.5 and 2.0 microns, depending on the size of the particle investigated. Measurements on an individual particle eliminates several factors present in powders. These factors include the interparticle interactions, and the averaging effect due to the particles' orientation. Magnetite and $\gamma-Fe_2O_3$ particles of about this size are close to the critical single domain size limit. Measurements on a roughly spherical, 1-micron particle of Fe_3O_4 showed the particle to be multidomained, since the net magnetisation could be varied continuously as a function of applied field. On the other hand, an acicular particle, about 1 micron in polar axis length, and 0.2-micron equatorial axis length, was found to have only discrete amounts of magnetization, and thus exhibited single domain properties. These results are in agreement with theoretical calculations.

G8. Effects of Spin-Orbit Coupling in Ferromagnetics. PETROS N. ARGYRES, *Westinghouse Research Laboratories.*—The conductivity and polarizability tensors of a ferromagnetic metal in an electromagnetic field have been calculated on the basis of the density matrix formalism. Electron-lattice interactions have been taken into account in a phenomenological way thus extending the validity of the formulas for all frequencies from zero to ultra-violet. The spin-orbit interaction gives rise to off-diagonal components of the polarizability and conductivity tensors which are proportional to the magnetization of the sample. This explains the occurrence of the anomalous Hall, Faraday, and Kerr effects in ferromagnetics. These formulas extend and synthesize the results of Karplus and Luttinger[1] and the author.[2]

[1] R. Karplus and J. M. Luttinger, Phys. Rev. **95**, 1154 (1954).
[2] P. N. Argyres, Phys. Rev. **97**, 334 (1955).

G9. On the Calculation of Curie Temperatures. HARRY A. BROWN, *Oberlin College.*—The Kramers-Opechowski method[1] of locating the transition point of a ferromagnetic (from the high-temperature series expansion of the partition function) has been pushed to the fifth step in the approximation for the body-centered cubic, simple cubic, and quadratic layer lattices

for arbitrary spin. Transition temperatures have been calculated for spin ½ to 3 giving in all cases series of approximations that converge satisfactorily and agree with the results of the Bethe-Peierls-Weiss method[1] where they are known. The failure of the Kramers-Opechowski method for the antiferromagnetic case will be discussed and detailed numerical results will be presented.

[1] W. Opechowski, Physica IV, 181 (1937).
[2] P. R. Weiss, Phys. Rev. 74, 1493 (1948).

G10. Application of the Bethe-Weiss Method to Ferrimagnetism. J. SAMUEL SMART, *U. S. Naval Ordnance Laboratory, White Oak, Maryland.*—The Bethe-Weiss theory[1] of ferromagnetism is extended and applied to a crystal containing two nonequivalent sets of sites for the magnetic atoms. Following Néel,[2] we designate the sites by A and B. Only nearest neighbor $A-B$ interactions are considered ($\alpha=\beta=0$, in Néel's notation). As expected, two different Curie temperatures are obtained, depending on the sign of the exchange interaction J. For $J>0$, the A and B magnetizations are parallel below the Curie temperature and for $J<0$, the A and B magnetizations are antiparallel below the Curie temperature. Expressions for the specific heat discontinuity and the susceptibility above T_c are derived. If the two sublattices are made equivalent, the equations for $J>0$ reduce to Weiss' equations for the ferromagnetic case while the equations for $J<0$ reduce to Li's equations for the antiferromagnetic case.[3] Specific results will be presented for some simple models of ferrimagnets and comparisons will be made with the Néel theory[2] results for the same models.

[1] P. R. Weiss, Phys. Rev. 74, 1493 (1948).
[2] L. Néel, Ann. phys. 3, 137 (1948).
[3] Y. Y. Li, Phys. Rev. 84, 721 (1951).

G11. Corrections to the Hall Potential in Ferromagnetic Materials.* EMERSON M. PUGH AND F. E. ALLISON, *Carnegie Institute of Technology.*—In evaluating the ordinary Hall coefficient, the Hall potential per unit current is normally plotted as a function of B. The slope of this curve is $R_0[1+4\pi(\alpha-1)\partial M/\partial B]/t$ and equal to R_0/t when $4\pi(\alpha-1)\partial M/\partial B \ll 1$: however, great care must be taken to insure that the fields used in determining R_0 are sufficiently high that this condition is satisfied. Two other sources of error are also important. The transverse temperature gradient arising from the Ettingshausen effect can superimpose a thermoelectric emf upon the Hall potential when the probes are made from a material other than that of the sample. Also when the sample is mounted between supports of a material other than the sample material, the Peltier effect produces a longitudinal temperature gradient, and the Nernst effect, which is associated with the temperature gradient, superimposes another transverse potential upon the Hall potential. Recent experimental data for an 80 percent Ni–20 percent Cu alloy at room temperature indicates that the Nernst potential may be as much as 6 percent of the Hall potential when no effort is made to suppress the temperature gradient.

* Supported by the Office of Naval Research.

G12. Hall and Nernst Effects in Ferromagnetic Materials.* F. E. ALLISON AND EMERSON M. PUGH, *Carnegie Institute of Technology.*—When both the Hall and Nernst effects contribute, the transverse potential per unit current should be of the form, $V/I=R_0(H+4\pi\alpha_H M)/t-A_N k w(H+4\pi\alpha_N M)\times(\partial T/\partial x)/I$, where t and w are the thickness and width of the sample, α_H and α_N the field parameters for the Hall and Nernst effects, A_N the Nernst coefficient, and k the thermal conductivity. A field parameter must be introduced for the Nernst effect since previous measurements[1] on ferromagnetic materials show that the Nernst potential has the same characteristics as the Hall potential. For a constant magnetic field V/I is a linear function of $(\partial T/\partial x)/I$ and the Hall potential can be obtained by extrapolation. For fields sufficiently high that $H\ll 4\pi\alpha_H M$ and $H\ll 4\pi\alpha_N M$, the ratio $R\alpha_H/A_N\alpha_N$ is given by kwt times the ratio of the slope to intercept.

* Supported by the Office of Naval Research.
[1] A. W. Smith, Phys. Rev. 33, 295 (1911).

G13. The Pyroelectric Effect in $BaTiO_3$. A. G. CHYNOWETH, *Bell Telephone Laboratories.*—Pyroelectric currents of square wave form are produced in single crystals of $BaTiO_3$ by illuminating them with chopped light from a tungsten lamp. It is shown that from room temperature up to the Curie point the pyroelectric effect is described by the same polarization function as is determined from measurements of the hysteresis loop. The experimental technique proves to be a very sensitive and nondestructive method for studying the behavior of the polarization of the crystal. The technique is used to study the pyroelectric effect induced by applied static electric fields at temperatures above the Curie point. The results are consistent with Devonshire's theory of the ferroelectricity of $BaTiO_3$ and they confirm that the Curie point transition is of the first order.

WEDNESDAY AFTERNOON AT 1:30

Mechanical Building

(J. A. BECKER presiding)

Surface Physics and Electronic Properties of Solids

Invited Papers

(H1 at beginning, H2 after H4)

H1. Ionization and Solubility of Impurities in Semiconductors. HOWARD REISS, *Bell Telephone Laboratories.* (25 min.)

H2. Adsorption Measurements Using Ion-Bombardment Cleaning and Low-Energy Electron-Diffraction Techniques. H. E. FARNSWORTH, *Brown University.* (25 min.)

Contributed Papers

H3. Effect of Ambients on the Thermoelectric Power and Conductance of Germanium Particle Aggregates. E. A. KMETKO, *Sylvania Electric Products Inc.*—The electrical and thermal resistances of aggregates of particles free of insulating surface films result almost entirely from the constriction of flow lines in the vicinity of the interparticle contact surfaces.[1]

In the case of germanium particles under small compressive loads the effective length of the constriction regions is comparable to the thickness of the space-charge layer. The thermoelectric power and dc conductance of such a system are, therefore, largely surface properties and an additional method is provided for investigating effects of various ambient atmospheres in shifting the bands at the surface. Thus far *n*-germanium has been studied using particles of $\sim 60\ \mu$ diameter obtained by crushing monocrystals. When the ambient is changed from oxygen to water vapor the conductance passes through a minimum which may be a small fraction of its initial value. The slope of the log (conductance) *vs* $1/T$ plot rises from values corresponding to activation energies <0.1 ev and goes through a maximum ~ 0.3 ev, while the thermoelectric power swings from positive to negative over a range as large as two to three hundred microvolts per degree.

[1] Ragnar Holm *Electric Contacts* (Gebers, Stockholm, 1946).

H4. Some Properties of the Iron Oxide-Alumina System. WALTER GRATTIDGE,* *General Electric Research Laboratory.*—The effects of additions of iron oxide to aluminum oxide have been studied for sintered samples in the range 0 to 20 percent Fe_2O_3 addition by weight. The electrical resistivity in air from room temperature to 1000°C is markedly reduced by the presence of iron oxide. For example, at 800°C the reduction in specific resistance is from about 9×10^7 ohm cm to 5×10^2 ohm cm for 20 percent iron oxide addition. The activation energy for electrical conductivity also decreases, from about 1.8 ev for zero addition to approximately 0.4 ev for 20 percent iron oxide addition. Firing tests indicate that the major solid state reactions occur in the temperature region 1350 to 1450°C. The results are described by the formation of a solid solution of the two spinels Fe_3O_4 and FeO Al_2O_3 together with excess Al_2O_3.

* This study has been carried out in cooperation with J. G. Stuart, General Electric Company.

H5. Work Function of the (100) Face of a Germanium Single Crystal as a Function of Heat Treatment and Ion Bombardment.* J. A. DILLON, JR., AND H. E. FARNSWORTH, *Brown University.*—The work function and photoelectric yield of the (100) face of a germanium single crystal are studied as functions of surface treatment. The work function of a gold plated reference is determined by the Fowler method, and the contact potential difference between this reference and the germanium crystal is measured by the Kelvin method. Before the tests, the crystal was given a CP-4 etch. Approximate values based on preliminary measurements are the following. Before baking, the contact potential difference is 0.37 volt with the germanium work function being lower than that of the gold. After baking *in vacuo* at 350°C for 10 hours, the germanium work function is 4.72 ev. After the crystal is further outgassed at 600°C for 2 hours the work function drops to 4.55 ev. Positive ion bombardment[1] of the germanium surface raises the work function to 4.75 ev. After a five minute annealing of the crystal at 500°C following the ion bombardment, the work function is 4.55 ev. Contamination of the surface by adsorption of residual gases decreases the work function and increases the photoelectric yield of this crystal face.

* Supported by a Joint Service's Contract with the Massachusetts Institute of Technology and a subcontract with Brown University.
[1] Farnsworth, Schlier, George, and Burger, J. Appl. Phys. **26**, 252 (1955).

H6. Effect of Adsorbed Hydrogen on the Field-Emission Current from the 310 and 210 Planes of Tungsten. J. A. BECKER, *Bell Telephone Laboratories.*—When hydrogen is adsorbed on a simple plane of tungsten such as the 310, it decreases the field-emission current i by a factor of 200. A plot of log i *versus* the adsorption time shows that adsorption takes place in three stages. At an H_2 pressure of 5×10^{-9} mm: the first stage ends after 1.5 min when $i/i_0=0.77$; the second stage ends after 3.7 min when $i/i_0=0.017$; the third stage ends after 6.0 min when $i/i_0=0.005$. For each stage i decreases rapidly, then more slowly, and approaches its limiting value. The third stage is desorbed at 380°K; the second stage at 580°K, and the first stage at 1000°K. The 210 plane also shows three stages of adsorption. The structure of these planes is such that a small electro-positive atom can be adsorbed below the outermost tungsten atoms and can thus form electro-negative dipoles, which decrease the emission. Each plane has two kinds of sites with different bond strengths and dipole moments. An adsorption stage ends when every alternate site is filled.

H7. Thin Film Interference Phenomena Applied to a Study of Gettering by Titanium. V. L. STOUT AND M. D. GIBBONS, *General Electric Research Laboratory.*—A step gauge of oxidized titanium was constructed and studies of the oxidation and dissolving of oxygen by titanium have been made. The oxidation was carried out at about 1000 microns of mercury oxygen pressure and the dissolving was done in vacuum. These studies show that different crystalline faces of hexagonal titanium oxidize at different rates. The parabolic oxidation law was found to hold for different individual faces. Dissolving of surface oxide was also dependent on the crystal face exposed. (A colored motion picture of the oxidation and oxide dissolving process on titanium will be shown.)

H8. Adsorption Measurements at Very Low Pressures. S. WAGENER, *Kemet Company.*—Rates of adsorption are measured by flowing the gas through a capillary to which ionization or Knudsen gauges are attached at both ends. From measurements of rates *versus* time, adsorbed quantities as low as 10^{-5} μg (equal to 1/1000 of a monolayer per cm^2) can be determined. The factors influencing the accuracy of this method are discussed. The method is used for studying the adsorption of several gases (mainly CO and H_2) on thin films of barium, magnesium, and nickel. Values are obtained for the probability of adsorption and for the dependence of adsorbed quantities on temperature and weight of the film. The activation energies for the adsorption of CO, CO_2, and O_2 are found to be smaller than 0.2 k cal/mole. Desorption phenomena are studied by reversing the flow of gas. Such studies are used for distinguishing between physical and chemical adsorption and for estimating the heat of adsorption.

H9. Electron Impact Studies with Dimethylamine.* HERMAN BRANSON AND NASIRA F. LEDBETTER, *Howard University.*—By varying the energy of the bombarding electrons in a 60° mass spectrometer, we have observed the following results for $(CH_3)_2NH$:

Mass	Ion	$A(x)$	$D(x)$	$I(x)$
45	$(CH_3)_2NH$	9.60		9.60
44	$(CH_3)_2N$	13.63	4.46	9.17
30	CH_2NH	13.53	3.07	10.46
29	CH_2N	15.39	6.75	8.64
15	CH_3	13.37	3.07	10.30
14	CH_2	18.92	6.87	12.05
14	N	25.13	10.68	14.45
13	CH	22.32	10.37	11.96
12	C	25.18	13.87	11.31

where $D(x)$ is the dissociation energy, $I(x)$ the ionization energy, and $A(x)$ the appearance potential of the ion in the mass spectrometer in electron volts. Thermochemical cycles were used for the derived results. These data give 3.07 ev for the energy of the N−C bond.

* His work is being supported by the U. S. Atomic Energy Commission and the Office of Naval Research.

H10. Dissociation of Solid Compounds by Electron Bombardment. GEORGE E. MOORE AND W. T. HUGHES,* *Bell Telephone Laboratories.*—Dempster,[1] using a mass spectrometer, first observed this phenomenon in 1918, but it has apparently never been investigated in any detail. We report here preliminary measurements on two types of solids, the alkali

chlorides and the alkaline earth oxides. A small demountable mass spectrometer contained the usual tungsten filament electron-bombardment source. Behind this was mounted an equipotential oxide-coated cathode and an anode coated with the solid compound to be dissociated. While calibrating the mass-to-charge scale, and during the experimental measurements, the cathode and tungsten filament operated at the same potential. Ions produced by electron impact dissociation of the compound on the anode are then displaced from their proper calibration position by the voltage accelerating the electrons from the cathode to anode. Both positive and negative ions are so displaced. The threshold energy of electrons able to produce ions by impact dissociation of a compound is apparently considerably greater than the heat of formation of the compound. Typical mass spectrograms will be shown. The technique should also be useful in studying the adsorption of thin films of simple compounds or elements.

* Now at Sandia Corporation, Sandia, New Mexico.
[1] A. J. Dempster, Phys. Rev. 11, 316 (1918).

H11. Field-Induced Surface Effects.* HENRY H. KOLM† AND GEORGE W. PRATT, JR.,† *Lincoln Laboratory.*—It was observed that the contact potential between identical electrodes in gaseous atmospheres is varied significantly by the application of a constant electric field, the work function of the negative electrode being increased relative to that of the positive electrode. Decay of the effect upon removal of the field is governed by a logarithmic law showing dependence upon the electrode material and nature of the gaseous atmosphere. A tentative explanation of the effect is offered, based on the assumption that the work function depends critically upon the equilibrium between adsorption and desorption rates at the gas-electrode interface, and that this equilibrium is affected by applied electrostatic fields of reasonable magnitude. This assumption is supported by the fact that field-induced absorption has been observed independently by direct experiments. It was found incidentally that use of the Kelvin method in gaseous atmospheres may lead to serious errors if conventional electrometer null detection methods are used, due to charge accumulation on a virtually ungrounded electrode.

* The research in this document was supported jointly by the Army, Navy, and Air Force under contract with the Massachusetts Institute of Technology.
† Staff Member.

THURSDAY MORNING AT 9:30

McLennan 135

(G. HERZBERG presiding)

Invited Papers

J1. Summary of Recent Research in Physics at McGill University. J. S. FOSTER, *McGill University.* (45 min.)

J2. Photonuclear Reactions: Some Theoretical Considerations. R. SKINNER, *University of Saskatchewan.* (20 min.)

J3. Photonuclear Reactions: Some Experimental Results. LEON KATZ, *University of Saskatchewan.* (20 min.)

J4. Lead Isotopes and the Earth's History. R. D. RUSSELL, *University of Toronto.* (30 min.)

THURSDAY MORNING AT 9:30

McLennan 132

(D. C. ROSE presiding)

Cosmic Rays

K1. Identification of Cosmic-Ray Shower Particles in Emulsions. I. Ionization-Scattering Method. C. J. D. JARVIS,* A. HUSAIN,* AND E. PICKUP, *National Research Council, Ottawa.*—A blob count *vs* scattering method has been used to identify medium energy particles ($p\beta \sim 50$ Mev-1 Bev) emitted in cosmic ray stars formed at high altitudes in Ilford G5 emulsions. Pions, K-mesons (mass $\sim 950 m_e$), protons, and deuterons have been identified, and in recent work there is no evidence for a group of particles of intensity about 7 percent with a mass intermediate between that of the 950 m_e group and the proton group as indicated by the Bristol results.

* National Research Laboratories Postdoctorate Fellow.

K2. Identification of Cosmic-Ray Shower Particles in Emulsions. II. Range-Scattering Method. B. JUDEK AND E. PICKUP, *National Research Council, Ottawa.*—Measurements are being made on long tracks (>3 cm) ending in the emulsion using the constant sagitta method. The results on the mass distribution of the particles, as well as the information on the accuracy of this method of measurement, will be reported.

K3. Charge Spectrum and Zenith Angle Distribution of Heavy Primary Nuclei Entering the Atmosphere. HERMAN YAGODA, *Natioanl Institutes of Health.*—Emulsions flown to a peak altitude of 135 miles in Viking rocket No. 9 have been studied for the tracks of nuclei of $Z \geq 6$. On the basis of 238 tracks identified by delta-ray counts in emulsions 1800 microns thick, the ratio of M-medium ($6 \leq Z \leq 10$) to H-heavy ($Z > 10$) nuclei is 2.66 ± 0.30. Of the heavy orimary nuclei, carbon is the most abundant. The $C-N-O$ nuclei appear to diminish in that order. Fluorine and neon constitute about 17 percent of the M-nuclei. Sodium and magnesium total about 30 percent of the H-nuclei. The spectrum also suggests minor peaks at silicon, sulfur, titanium, and iron. The tracks of Li$-$Be$-$B nuclei have been observed, $R_{LM} \leq 0.3$, but their primary nature cannot be established. The omnidirectional flux of $Z \geq 6$ at the top of the atmosphere is estimated at 7.4 ± 1.3 per m^2·sec. steradian at λ 41°N. Within the limits of error the zenith angle distribution of the tracks, corrected geometrically, indicates an essentially isotropic flux in the upper hemisphere. The directional flux is in good agreement with geomagnetic

theory for zenith angles $<60°$. Theory predicts a marked diminution in flux for zenith angles $>60°$ which is not in accord with the present observations.

K4. Cosmic-Ray Proton Spectrum at Sea Level. K. W. OGILVY, *National Research Council, Ottawa.*—The application of the Čerenkov counter "heavy-particle selector" to the study of the cosmic-ray proton component will be discussed. Experiments will be described by which the flux in the energy region 230 to 480 Mev has been measured, and some further information on the spectrum between 150 to 700 Mev has been obtained. The barometer coefficient for protons has been measured and found to be 0.65 ± 0.08 percent/mb equal to that for neutrons within the experimental error.

K5. Directional Intensity Studies of Cosmic Rays. JOHN KATZMAN, *National Research Council, Ottawa.*—Three identical cosmic-ray telescopes, mounted on an iron frame turntable, were employed to study the asymmetry and the zenithal-angle dependence of the hard component of cosmic rays. Two of the telescopes were mounted so that they would be fixed in steps of 5° to the zenith. The third telescope fixed in the vertical position was used as a monitor to avoid the necessity of calculating approximate corrections for changes in temperature and pressure of the atmosphere. The zenithal dependence of the intensity, $I_\theta = I_0 \cos^n\theta$, was obtained for 10 different angles in the east-west plane; $n=2.3\pm0.4$ at 10° to $n=1.96\pm0.01$ at 70° in the easterly direction and $n=2.00\pm0.4$ at 10° to $n=1.94\pm0.01$ at 70° in the westerly direction. The asymmetry in the east-west plane varied from 0.1 percent ±0.3 percent at 10° to 1.3 percent ±0.6 percent at 70°.

K6. On the Neutron Production by Cosmic Rays. K. W. GEIGER, *National Research Council.*—Materials of various atomic weights were placed in a paraffin pile containing two large $^{10}BF_3$ counters and the production of evaporation neutrons due to interaction of cosmic rays was investigated at sea level. A wide-angle cosmic-ray telescope on top of the producer made it possible to distinguish between the ionizing and the total neutron producing component. Events with different numbers of neutrons detected from one interaction were recorded separately so that the neutron multiplicity could be worked out. In 0.75 inch of lead an average multiplicity of 6 due to the total neutron producing component and 10 due to the ionizing part only has been fuond. This is consistent with the fact that, in the nucleonic component which is mostly responsible for the neutron production, the average energy of protons is higher than that of fast neutrons capable of producing interactions. The multiplicity has been found to increase with atomic weight approximately proportional to A^1.

Invited Papers

K7. Work Done with Nuclear Emulsions at Université de Montréal. P. DEMERS, *Université de Montréal.* (30 min.)

K8. Cosmic-Ray Measurements at Sea Level over Wide Ranges of Latitude. D. C. ROSE, *National Research Council, Canada.* (30 min.)

K9. Prospective Cosmic-Ray Observation during the International Geophysical Year. S. A. Korff, *New York University.* (30 min.)

THURSDAY MORNING AT 9:30

Wallberg Building

(B. W. SARGENT presiding)

Radioactive Substances; Neutron Physics

L1. Radioactive Decay of Ga^{72}. M. W. JOHNS, B. C. CHIDLEY, AND I. R. WILLIAMS, *McMaster University.*—The beta and gamma radiations from 14 hr Ga^{72} have been studied with a high resolution beta-ray spectrometer and two NaI(Tl) spectrometers used in coincidence. Gamma transitions of the following energies and relative intensities were found: 601(7), 630(21), 690(I.C. only), 768(3), 810(3), 834(93), 894(10), 1050(7), 1317(2), 1463(4), 1595(6), 1859(6), 2203(30), 2491(10), 2508(17), 2827(0.4), 3086(0.04), and 3350(0.02) kev. An analysis of the beta spectrum reveals five groups with the following end-point energies and intensities: 637(42 percent), 959(31 percent), 1508(10 percent), 2529(9 percent), and 3166(8 percent)kev. Coincidence measurements will be discussed and a decay scheme proposed.

L2. A New Zinc Isotope, Zn^{61}.* JAMES B. CUMMING, *Brookhaven National Laboratory.*—A 1.5 ± 0.1 min period was observed in the gross decay curve of nickel bombarded with 18-Mev alpha particles. This activity accompanied the 38 min Zn^{63} on separation of zinc from Ga, Cu, Ni, Co, Fe, and Mn by anion exchange. The decay curve of zinc separated in this manner showed a tail of Cu^{61} in the amount expected if it were the daughter of the 1.5 min activity. The fact that the known 200 min Cu^{61} grows from the new zinc activity was confirmed by periodic milkings. Additional support for the assignment of the 1.5 min activity to Zn^{61} came from the observation of the increase in the ratio of the yield of Zn^{61} to that of Zn^{63} when nickel enriched in Ni^{58} replaced normal nickel as the target. A scintillation spectrometer study showed that Zn^{61} decays predominantly by the emission of 4.9 ± 0.5 Mev positrons to the ground state of Cu^{61}.

* Research performed under the auspices of the U. S. Atomic Energy Commission.

L3. Dual Decay of the 50-Day In^{114} Isomer.* J. N. BRAZOS AND R. M. STEFFEN, *Purdue University.*—It is well known that the decay of the 50-day In^{114} isomer to Cd^{114} is followed by several gamma rays of energies 0.556 Mev, 0.576 Mev, 0.722 Mev, 1.30 Mev, and 1.27 Mev. The problem of the spins of the Cd^{114} levels, however, as well as the question whether the Cd^{114} levels are reached directly by electron capture from the 50-day isomeric state or from the 72-sec ground state has not been satisfactorily answered. The polarization-directional correlation of the 0.722 Mev−0.556 Mev gamma cascade was measured and the result cannot be reconciled with the assumption of a mixed $M1+E2$ transition (0.722 Mev) followed by an $E2$ transition (0.556 Mev) and the spin assignment 2, 2, 0, as proposed first by Klema and McGowan,[1] but rather indicates a $4-E2-2-E2-0$ cascade.[2] The directional correlation of this cascade as measured with differential energy selection also favors the latter assignment. This spin sequence implies that the 0.722 Mev−0.556 Mev gamma cascade is reached predominantly by direct electron capture[3] from the 50-day In^{114} isomer of spin 5. The latter

also decays by a converted gamma transition to the 72-sec ground state.

* Supported by the U. S. Atomic Energy Commission.
[†] E. C. Klema and F. K. McGowan, Phys. Rev. **87**, 524 (1952).
[‡] R. M. Steffen, Phys. Rev. **83**, 166 (1951).

L4. Decay of the 72-sec In^{114} Ground State.* R. M. STEFFEN AND J. N. BRAZOS, *Purdue University.*—Using a NaI (Tl) scintillation spectrometer in conjunction with a twenty-channel pulse-height analyzer the gamma spectrum following the electron capture of the 72-sec ground state of In^{114} was measured. The 72-sec activity was produced by deuteron bombardment of Cd and In foils. Photopeaks due to gamma rays of 0.560 Mev, 0.722 Mev, and 1.30 Mev were observed. The intensity ratio of the gamma rays is approximately 4:2:1, whereas the intensity ratio of the gamma rays emitted from the 50-day In^{114} activity in equilibrium with the 72-sec decay of the ground state is 1:1:0.05. This difference shows conclusively that Cd^{114} levels are reached directly from the 72-sec ground state in In^{114} as well as from the 50-day isomeric state (compare preceding abstract). Coincidence measurements indicate that a triple gamma cascade of electric quadrupole radiation with energies of 0.572 Mev, 0.722 Mev, and 0.556 Mev between states of spin 2, 4, 2, and 0 follows the electron capture of the 72-sec state. The directional correlation of the 0.572 Mev−0.556 Mev is, within the limits of error, isotropic which is consistent with the fact that this is a 1–3 cascade.

* Supported in part by the U. S. Atomic Energy Commission.

L5. Thermal Neutron Capture Cross Section of Au^{198} and the Half-Life of the 209-Kev State in Hg^{199}. R. L. GRAHAM, R. E. BELL, L. YAFFE, AND J. S. GEIGER, *Chalk River Laboratories.*—Radioactivities resulting from successive neutron captures in Au^{197} have been studied with an end-to-end pair of lens spectrometers and millimicrosecond coincidence techniques. From (i) the relative intensities of the Au^{198} and Au^{199} β-spectrum components in a particular source, (ii) the Au^{198} source strength, as determined by coincidence measurements in the same source, (iii) the epi cadmium Au^{198} activity observed under the same irradiation conditions, and (iv) the pile power log, the thermal neutron capture cross section of radioactive Au^{198} is obtained in terms of the known thermal cross section of Au^{197}. Four such values were obtained from irradiations in the Brookhaven, NRX, and MTR piles, using fluxes of from 4×10^{12} to 9×10^{13} neutrons cm^{-2} sec^{-1}. These show no dependence, within the errors, on flux or neutron temperature, and give a weighted average of 26 000±1200 barns. Limits on the amount of Au^{200} activity show that any error caused by capture in Au^{199} is <3 percent. The half-life of the 209-kev $M1$ γ transition in Hg^{199} is found to be $7\pm4)\times10^{-11}$ sec by the self-comparison method[1] in agreement with other odd neutron $M1$ transitions.[1]

[1] R. L. Graham and R. E. Bell, Can. J. Phys. **31**, 377 (1953).

L6. Decay of Au^{194} and Au^{196}.* M. T. THIEME AND E. BLEULER, *Purdue University.*—A double-coil lens spectrometer, adapted for coincidence measurements, has been used to study the decay schemes of Au^{194} and Au^{196}. The electron capture transitions of the latter to the 685-kev, the 354-kev, and the ground state of Pt^{196} have relative intensities of 29.4 :70.6:~0. The conversion coefficients show the lower gamma ray (354 kev) to be an $E2$ transition, the upper one (331 kev) a mixture of $E2$ and (3±1) percent $M1$, in agreement with angular correlation data. The level scheme of Pt^{194} as known from the decay of Ir^{194} was verified and additional high-energy levels at 2.15, 2.24, and 2.3 Mev were found. They are reached by allowed electron capture from Au^{194} whereas the decay to the ground state and the first excited state is by first forbidden transitions, with maximum positron energies of 1.55 and 1.21 Mev. It is probable that the Au^{194} ground state is 2^-. The conversion coefficients of the two low-energy gamma rays (291 and 327 kev) indicate $E2$ transitions. Tentative spin and multipole order assignments will be given for the other levels and transitions in Pt^{194}.

* Supported by the U. S. Atomic Energy Commission.

L7. Some Decay Properties of Tl^{195}, Tl^{197}, and Tl^{198m}.* J. D. KNIGHT† AND E. W. BAKER, *Brookhaven National Laboratory.*—The nuclides Tl^{195} ($t_{\frac{1}{2}}=1.25\pm0.1$ hours) and Tl^{197} ($t_{\frac{1}{2}}=2.8\pm0.2$ hours) have been prepared by 21-Mev deuteron bombardment of enriched Hg^{196} and Hg^{198} and have been identified by timed chemical separations of their Hg daughters. Both Hg daughter activities are those of the ground-state isomers. Tl^{197} has also been prepared by alpha bombardment of Au, and its assignment has been supported by stacked-foil excitation function experiments. Gamma rays and conversion electrons from $Tl^{197-200}$ sources were examined by scintillation spectrometer and 180° beta-ray spectrograph. Of the Tl^{197} gamma transitions reported by previous investigators,[1] the one at 152 kev was confirmed and those at 434, 588, and 637 kev were observed; the latter two probably belong to Tl^{198m}, but are converted in Hg. Previously unreported conversion lines found at 816, 753, 451, 436, 429, 358, 339, 306.5, 292, 221, and 210 kev are tentatively assigned to Tl^{198m}. Additional new lines at 1115, 924, 715, and 132 kev are tentatively assigned to Tl^{198}; some of the lines presumably occur in electron-capture decay of both Tl^{198} isomers. Tl^{198m} decays roughly 60 percent by electron capture.

* Research carried out under the auspices of the U. S. Atomic Energy Commission.
† On temporary assignment from Los Alamos Scientific Laboratory.
[1] Andersson, Arbman, Bergström, and Wapstra, Phil. Mag. **46**, 70 (1955).

L8. The Nitrogen Cross Section near Threshold.* B. G. CHIDLEY AND L. KATZ, *University of Saskatchewan.*—A number of resonance peaks have been observed in the (γ,n) cross section of N^{14} in the region between threshold and the giant resonance. In this region, from 10.5 Mev to 16 Mev, there appears a peak at ~12.7 Mev of half-width ~1 Mev and a peak at ~11.5 Mev of half-width ~0.3 Mev. There is some evidence of a very small peak at ~10.8 Mev. These measurements were obtained by using the bremsstrahlung spectrum of the University of Saskatchewan betatron which has been highly stabilized with a new energy control. Most of these measurements have been made through detection of the residual N^{13} activity but, as it had been suggested that the dip in the cross-section curve might be due to competition of a $(\gamma,2n)$ reaction which would not be detected by residual activity, the cross section has also been measured by detection of the emitted neutrons.

* Supported by the National Research Council of Canada.

L9. Total Neutron Cross Sections of Light Elements. R. L. BECKER, R. B. PERKINS, AND H. H. BARSCHALL, *University of Wisconsin.**—The total neutron cross sections of several light elements were measured with a neutron energy spread of about 20 kev in the neutron energy ranges between 4.4 and 5.5 Mev and between 7.5 and 8.7 Mev. Peaks in the total cross section of carbon occurred at neutron energies of 5.00, 5.42, and 7.82 Mev. In addition a broad peak extends from 7.5 to 8.5 Mev. This peak probably contains several additional unresolved resonances.

* Work supported by the U. S. Atomic Energy Commission and the Wisconsin Alumni Research Foundation.

L10. Energy and Angular Distributions of Photoneutrons. W. R. DIXON, *Queen's University.*—A study has been made of photoneutrons from targets irradiated in the 70-Mev x-ray beam of the Queen's University synchrotron. The energy distributions of photoneutrons from copper and lead have

been determined with nuclear emulsions. It is found that most of the neutrons can be accounted for by an evaporation process which appears to be governed by a constant nuclear temperature. The temperature found for copper is 1.2 Mev and for lead is 1.0 Mev. The angular distributions of photoneutrons from lead, tin, copper, iron, aluminum, carbon, and beryllium have been measured with a zinc-sulfide-Lucite scintillation detector. There are pronounced peaks at 90° in carbon and beryllium; the relative magnitude of this anisotropic component seems to decrease with increasing A.

THURSDAY MORNING AT 9:30

Mechanical Building

(A. WEXLER presiding)

Electron Conduction in Solids

Invited Papers

(M1 at the beginning, M2 after M4)

M1. Optical Absorption by Conduction Electrons in Solids. T. HOLSTEIN, *Westinghouse Research Laboratories.* (25 min.)

M2. Electron Transport Properties of Solids at Low Temperatures. D. K. C. MACDONALD, *National Research Council (Canada).* (25 min.)

Contributed Papers

M3. Infrared Absorption of Copper and Silver at 4.2°K. MANFRED A. BIONDI, *Westinghouse Research Laboratories.*—In sufficiently pure metals at low temperatures, the classical mean free path of the conduction electrons becomes much larger than the skin depth of penetration of the electromagnetic field, and therefore the classical Drude-Lorentz theory no longer describes the absorptivity of the metals. It has recently been shown[1,2] that two processes are of importance in determining the absorption of radiation under these conditions. In the first, an electron absorbs a photon and simultaneously suffers diffuse reflection from the surface of the metal to conserve momentum and energy. In the second, an electron absorbs a photon and generates a phonon to permit conservation of momentum and energy. In order to test these theories, we have measured the absorptivity of copper and silver samples at liquid helium temperatures over the wavelength range 0.36–3.4 μ. For radiation which does not cause interband transitions ($\lambda > 1\ \mu$) it is found that the measured absorption is independent of wavelength, in agreement with theory. The measured values of the absorptivity, $A = 0.0049$ for copper and 0.0044 for silver, are in good agreement with the theoretical values of 0.0049 and 0.0046, respectively. An extrapolation of the measured absorptivity is consistent with the results of Chambers[3] at microwave frequencies.

[1] G. E. H. Reuter and E. H. Sondheimer, Proc. Roy. Soc. (London) **A195**, 33 (1948), and T. Holstein, Phys. Rev. **88**, 1427 (1952).
[2] T. Holstein, Phys. Rev. **96**, 535 (1954).
[3] R. G. Chambers, Proc. Roy. Soc. (London) **A215**, 481 (1952).

M4. Anomalous Skin Effect at Low Frequencies. M. P. GARFUNKEL AND L. J. VARNERIN, JR., *Westinghouse Research Laboratories.*—Absorption of energy from an alternating magnetic field in metallic samples having high electrical conductivity has been measured at liquid helium temperatures. Spherical samples, suspended in poor thermal contact with a liquid helium bath, were surrounded by a coil which maintained the alternating field. On application of the alternating field the temperature rise of the sample permits determination of the absorption. In this way, absorptivity was obtained as a function of frequency in the range 10 cps to 2×10^6 cps. The conductivities of samples of copper and tin were such that the skin depth was equal to the electron mean free path at about 1000 cps. Data obtained on copper and tin spheres are compared with predictions from the theory of the anomalous skin effect developed by Reuter and Sondheimer.[1]

M5. Secondary Electron Emission from Magnesium Oxide Single Crystals.* ROBERT G. LYE, *University of Minnesota.*—A pulsed collector method has been used to measure δ, the secondary emission ratio, from stoichiometric and oxygen colored crystals of MgO, for primary electron energies between 100 and 10 000 volts. Crystals cleaned in air and transferred to the measuring tube under optimum conditions exhibit maximum yields near 12.5 at 1000 volts, independently of the concentration of excess oxygen. Preliminary measurements from crystals cleaved *in situ* in the evaucated measuring tube indicate that greater yields may be obtained from surfaces free of absorbed gases. The results will be discussed in terms of current theories of secondary electron emission.

* Supported by U. S. Army Signal Corps.

M6. Secondary Electron Emission and Color Centers. A. J. DEKKER, *University of Minnesota.**—Secondary electrons, produced in an insulator by bombardment with a beam of primary electrons, interact with phonons, color centers, and other types of lattice defects. The interaction with phonons gives rise to a temperature dependent secondary yield. The possible influence of color centers on the secondary yield will be discussed in the light of a theory of the escape mechanism suggested by the author.[1]

* Supported by U. S. Army Signal Corps.
[1] A. J. Dekker, Phys. Rev. **94**, 1179 (1954); Physica **21**, 29 (1955).

M7. Photoelectric Emission from Metals into Magnesium Oxide.* W. T. PERIA, *University of Minnesota.*—Measurements of the photoelectric emission from various metallic electrodes into MgO single crystals, and of the photoconductive response of a MgO crystal containing excess Mg have been performed. The variation of yield with wavelength is in accord with the Fowler equation for metallic photoemission, over most of the measured range. Values of the depression of the metallic work functions due to the presence of the insulator have been obtained. For the case of the excess Mg crystal a compatible

value was obtained by assuming that the conduction electrons originated in small metallic Mg particles.

* Supported by U. S. Army Signal Corps.

M8. Deterioration of Luminescent Phosphor under Positive Ion Bombardment. J. R. YOUNG, *General Electric Research Laboratory.*—The reduction of luminescence of ZnS:Ag phosphor has been observed after bombarding with H^+, H_3^+, He^+, Ne^+, N_2^+, and A^+ ions having energies from 1 to 25 kev. Deterioration was observed by exciting the phosphor by electrons. Detectable deterioration could be observed after a bombardment of less than 10^{-9} coulomb/mm² of ions (5×10^{11} ions/cm²) had struck the phosphor. The deterioration could be annealed out at temperatures between 450°C–700°C. Results indicate that light 25-kev ions probably penetrate between 0.1 μ and 0.2 μ into the phosphor.

M9. Optical Studies of Avalanche Breakdown in Silicon. K. G. MCKAY AND A. G. CHYNOWETH, *Bell Telephone Laboratories.*—We have established that the recently reported[1] visible light from silicon $n-p$ junctions is a true volume effect and is not necessarily associated with the surface. A thin (~2 microns) n-layer is diffused into p-type silicon, yielding a geometry such that light produced anywhere in the junction can traverse the n-layer without excessive attenuation and be viewed directly. Light emitted from the intersection of the junction with the surface is yellowish-white and appears to be substantially in agreement with that previously reported.[1] However, light emitted elsewhere has a spectrum shifted to the red. That this light is generated in the volume is shown by the fact that estimates of n-layer thickness obtained from the spectrum shift together with absorption data, agree roughly with the values given by diffusion data. The light is emitted from fixed sources which are usually a micron or less in diameter. The number of light sources increases with increasing junction current. The effect of this on the theory of breakdown will be considered. The technique is useful for the study of junction uniformity and the effects of imperfections on breakdown.

[1] Newman, Dash, Hall, and Burch, Bull. Am. Phys. Soc. 30, No. 2, 13 (1955).

M10. Microplasmas in Silicon. D. J. ROSE AND K. G. MCKAY, *Bell Telephone Laboratories.*—The appearance of light in reverse-biased silicon junctions indicates that there exist localized regions of high current density. These regions arise from an instability at breakdown which occurs at discrete points. The instability results from multiplication of both electrons and holes by ionization, and distortion of the electric field by mobile space charge. The high current density microplasma possesses many of the characteristics of the gas discharge cathode fall. Some microplasmas are intermittent; the current in these can be measured, and is about 50 microamp. Qualitative calculations have been made, based on the measured ionization coefficient and current. They show that the microplasma should occupy a volume of the order of a few hundred angstroms diameter, and that the voltage drop across it should be about 5 volts. The total number of mobile carriers in the microplasma at any time is about 20–40. The intermittent nature may be explainable on the basis of a statistical fluctuation, wherein all the carriers fail to ionize.

M11. The Distribution of Electrons Scattered in Solids.* L. MARTON, J. AROL SIMPSON, AND T. F. MCCRAW, *National Bureau of Standards.*—In an extension of the work previously reported on the energy and angular distribution of 20-kev electrons scattered in gold,[1] we have measured this distribution for several low Z elements. It is found that the fall-off of intensity with angle for aluminum is much faster than for the other elements measured. The intensity for aluminum changes by a factor of 10 000 in approximately 1.2×10^{-2} radian, while there is only a factor of 500 for gold, 200 for beryllium, and 200 for carbon in the same angular range. An apparent anomaly exists in that the diffraction maxima for carbon and beryllium are centered on a characteristic energy loss rather than on the zero loss position as found for gold and aluminum. Cartographic presentations of these results will be shown, and these points discussed further.

* This work was supported by the Office of Naval Research.
[1] Bull. Am. Phys. Soc. 30, No. 1, 29 (1955).

THURSDAY AFTERNOON AT 2:00

McLennan 135

(R. T. BIRGE presiding)

Invited Papers

N1. Some Recent Work on the Ultraviolet Spectra of Simple Molecules. A. E. DOUGLAS, *National Research Council, Canada.* (30 min.)

N2. Optical Absorption and Reflectivity of Alkali Halides in the Far Ultraviolet. P. HARTMAN, *Cornell University.* (30 min.)

N3. Electronic Band Configuration of Mixed Linear Lattices. E. KERNER, *University of Buffalo.* (30 min.)

N4. Radio-Frequency Spectra of Nuclei in Crystals. G. M. VOLKOFF, *University of British Columbia.* (30 min.)

THURSDAY AFTERNOON AT 2:00

McLennan 132

(J. S. FOSTER presiding)

Reactions of Transmutation

Q1. Angular and Energy Distributions of Photoprotons from Aluminum, Copper, Rhodium, and Gold. W. K. DAWSON, *Queen's University.*—Thin foils of aluminum, copper, rhodium, and gold were bombarded by the x-ray beam from the 70-Mev synchrotron. The resulting photoprotons were detected by means of 200-micron Ilford C_2 emulsions in a moving-plate

camera which enables energy distributions up to about 16 Mev and angular distributions from 20 to 160 degrees with respect to the beam to be determined. The experimental energy distributions have been compared to evaporation theory with a nuclear temperature independent of excitation energy and/or a photoelectric $E^{-7/2}$-formula. The observed energy distributions can be fitted with constant temperatures of 2.1, 1.3, and 1.0 Mev for aluminum, copper, and rhodium, respectively. The angular distribution of photoprotons of energies greater than 8 Mev from aluminum shows a pronounced forward asymmetry. The photoprotons from copper have an isotropic distribution. The angular distribution for rhodium peaks at approximately 80 degrees with respect to the x-ray beam.

Q2. $C^{13}(\alpha,n)$ Reaction. R. B. Walton, R. L. Becker, J. D. Clement, and M. S. Zucker, *University of Wisconsin.**—The forward yield of the $C^{13}(\alpha,n)$ reaction was measured for bombarding energies between 1.6 and 3.8 Mev. Peaks in the forward yield were observed at α-particle energies of 2.25, 2.44, 2.70, 2.78, 2.83, 3.09, 3.36, and 3.43 Mev. At the lowest and highest energies the reaction cross section is about one millibarn per steradian; at the resonances peak cross sections of about 40 millibarns per steradian are reached. Measurements of the yield at 90° with respect to the incident α particles showed the same maxima that were observed at 0° except that the 2.45-Mev maximum is shifted to 2.40 Mev and an additional peak is resolved at 2.62 Mev.

* Work supported by the U. S. Atomic Energy Commission and the Wisconsin Alumni Research Foundation.

Q3. Energy Levels in F^{19}. J. W. Butler and H. D. Holmgren, *Naval Research Laboratory.*—A search for gamma-emitting levels in F^{19} between 8.3 and 9.8 Mev of excitation energy has been made by bombarding a 0.005-mil NiO target (39 percent O^{18})[1] with protons of energy 0.3 to 2.0 Mev. Resonances in the gamma-ray yield were observed with the aid of a 3 in. × 3 in. sodium iodide crystal and a 20-channel analyzer. Resonances were observed at 630±2, 849±3, 1169±2, 1399±5, 1685±5, 1769±2, 1931±2 kev proton energy, with respective widths of 2.6, 40, <0.9, <15, <15, 4.0, and 1.5 kev. The lower two levels are known α emitters and the upper two resonances were observed by Hudspeth *et al.*[2] at slightly different energies. The cascade schemes are complicated, leading to a fairly flat spectrum with a high energy cutoff approximately equal to the excitation energy. The 9.062-Mev level (1169-kev resonance) decay spectrum did, however, show a preference for decay via the 2.8-Mev state. The 9.062-Mev level is at about the right position to correspond with the 1.47-Mev level in O^{19}, and therefore possibly these two levels are members of an isobaric spin quartet. The narrowness of the level is consistent with this hypothesis since a $T=3/2$ state in F^{19} could not emit an alpha particle leaving N^{15} in the ground state.

[1] The enriched O^{18} was kindly supplied by Professor A. O. C. Nier.
[2] Hudspeth, Morgan, and Peoples, Bull. Am. Phys. Soc. **30**, No. 3, 43 (1955).

Q4. Properties of Some Excited States In Mg^{24}.† R. W. Krone, N. P. Baumann,* and F. W. Prosser, Jr.,* *University of Kansas.*—Investigation of those states in Mg^{24*} attainable by the proton bombardment of Na^{23} has been continued using the University of Kansas Van de Graaff generator. The resonance curves for the various reactions yielding x-rays were obtained from $E_p=0.98$ to 1.50 Mev using a method similar to that of Stelson and Preston.[1] In general the results agreed with theirs, with the exception that further prominent capture resonances were found at energies of 0.989, 1.022, 1.176, 1.287, 1.321, and 1.400 Mev in addition to the one at 1.419 Mev. At most of these resonances where capture occurs, the de-excitation takes place predominantly by only one of the several possible cascades. At those resonances where this is true and where the initial transition is the highest in energy, the angular distribution of this radiation has been measured. The results will be discussed in terms of the possible spin and parity assignments of the states in Mg^{24*}.

† Supported in part by the National Science Foundation.
* National Science Foundation Predoctoral Fellows.
[1] P. H. Stelson and W. M. Preston, Phys. Rev. **95**, 975 (1954).

Q5. Gamma Radiation from the Proton Bombardment of Mg^{25}. G. A. Bartholomew, H. E. Gove, A. E. Litherland, and E. B. Paul, *Chalk River Laboratories.*—The study of the gamma rays from proton bombardment of Mg^{25} has been extended to the resonances at 0.418 and 2.40 Mev. Strong inelastic scattering at the 2.40-Mev resonance has been observed by means of the 1.38-Mev γ ray resulting from the de-excitation of the residual nucleus. Absolute γ-ray yields and angular distributions have been measured at these resonances. Further angular distribution measurements have been made at resonances previously reported.[1] As a result of the angular distribution work J-values of five more of the excited states of Al^{25} can be assigned. The J-values and known parities[2] together with the excitation energy are as follows: 0.95 Mev, 3/2+; 2.70 Mev, 3/2+; 3.88 Mev, 5/2+; 4.22 Mev, 3/2+; 4.60 Mev, 5/2+.

[1] E. B. Paul *et al.*, Bull. Am. Phys. Soc. **30**, No. 3 (1955).
[2] P. M. Endt and J. C. Kluyver, Revs. Modern Phys. **26**, 95 (1954).

Q6. Gamma Rays from the Reaction $Mg^{25}(p,p'\gamma)$. H. E. Gove, A. E. Litherland, E. B. Paul, and G. A. Bartholomew, *Chalk River Laboratories.*—To complement the study[1] of Al^{25} the reaction $Mg^{25}(p,p'\gamma)$ was investigated for incident proton energies between 1.90 and 2.98 Mev. A separated target[2] of Mg^{25} (96 percent) was used and the gamma rays from inelastic proton scattering were measured in a large NaI(Tl) crystal. About 20 resonances in Al^{26} were found and some or all of the following gamma rays were observed at each resonance; 0.40, 0.58, 1.61, 1.96, and 2.56 Mev. The 0.40-Mev gamma ray was observed to be in coincidence with some of the 0.58-Mev, indicating that a level at 0.98 Mev in Mg^{25} decays by a direct transition to the ground state and by a stop-over transition to a level at 0.58 Mev. The branching ratio of the 0.40-Mev gamma ray to that of 0.98 Mev is 1.06. All the gamma rays observed with the exception of the 0.40 represent direct transitions to the ground state of Mg^{25} and correspond to previously-known levels in this nucleus.[3]

[1] A. E. Litherland *et al.*, Bull. Am. Phys. Soc. **30**, No. 3 (1955) and accompanying abstract.
[2] Obtained from A. E. R. E. Harwell.
[3] P. M. Endt and J. C. Kluyver, Revs. Modern Phys. **26**, 95 (1954).

Q7. Competition Between p,pn and $p,2p$ Reactions on Ce^{142}.* A. A. Caretto, Jr., and G. Friedlander, *Brookhaven National Laboratory.*—Cross sections for the production of Ce^{141} by p,pn and of La^{141} by $p,2p$ reactions on Ce^{142} have been measured at 0.38 and 1.0 Bev. For a pure "knock on" mechanism the ratio of $\sigma_{Ce^{141}}/\sigma_{La^{141}}$ should be approximately equal to the neutron to proton ratio in the target nucleus, which is 1.45. If the reaction mechanism involves the evaporation of the second particle from a Ce^{142} compound nucleus, a larger value is expected for the ratio $\sigma_{Ce^{141}}/\sigma_{La^{141}}$. The following data were obtained:

Energy Bev	$\sigma_{Ce^{141}}$ mb	$\sigma_{La^{141}}$ mb	$\frac{\sigma_{Ce^{141}}}{\sigma_{La^{141}}}$
0.38	87.3	57.7	1.53
1.00	31.6	17.4	1.80

To determine the relative probabilities of neutron and proton

evaporation from a Ce^{142} compound nucleus, the excitation curves for the reactions $Ba^{138}(\alpha,n)Ce^{141}$ and $Ba^{138}(\alpha,p)La^{141}$ were measured with 10–40 Mev α particles. Between 25 Mev and 40 Mev the ratio $\sigma_{Ce^{141}}/\sigma_{La^{141}}$ varies between 3 and 4. It is thus concluded that, at least at 0.38 Bev, the mechanism for p,pn and $p,2p$ reactions is predominately "knock on."

* Work performed under the auspices of the U. S. Atomic Energy Commission.

Post-Deadline Papers, If Any

THURSDAY AFTERNOON AT 1:30

Mechanical Building

(G. A. WOONTON presiding)

Electron Emission and Ejection Phenomena

Invited Papers

(R1 at beginning, R2 after R9)

R1. Studies of the Thermionic Emission from Single-Crystal Tungsten. A. R. HUTSON, *M.I.T.* (25 min.)

R2. The Influence of an Electric Field on the Work Function of an Oxide-Coated Cathode. H. J. KRUSEMEYER, *Bell Telephone Laboratories.* (25 min.)

Contributed Papers

R3. Temperature Scale for Molybdenum.* G. J. BALDWIN, J. L. SHILTS, AND E. A. COOMES, *University of Notre Dame.*—A new experimental determination of the temperature scale for molybdenum has been made. The purpose of this work was to provide an accurate temperature scale for electronic research and to evaluate the conflict in data[1,2] which have been published on the spectral emissivity of this metal. A thin-walled molybdenum cylinder was used as a blackbody for the measurement of spectral emissivities; these results were checked on wires at low temperature with a reflectometer. Resistivities and total emissivities were obtained from current and potential measurements on a number of wires having diameters of the order of 10 mils. Temperatures were determined with an optical pyrometer constructed specifically for work with fine wires and calibrated at the Bureau of Standards. Results for the temperature range 1000 to 2400°K are presented in graphic and tabular form, with extrapolation to the melting point. The present values are shown to correspond closely with those of Worthing.

* This research was sponsored by the U. S. Navy Bureau of Ships.

[1] L. V. Whitney, Phys. Rev. **48**, 458 (1935).
[2] A. G. Worthing, Phys. Rev. **28**, 190 (1926).

R4. Cause and Elimination of Anomalous Flicker Effect.* W. W. LINDEMANN, *Electrical Engineering Department, University of Minnesota.*—Vacuum tubes with tungsten filaments show a large amount of noise above the ordinary shot effect when operated in the space charge limited region. This noise appears in the frequency range between 10 cps and 100 kc and has a spectrum of the type $C/(1+\lambda^2\gamma^2)$. Experiments to determine the exact nature, cause, and method for eliminating this type of noise will be discussed.

* Work supported by the U. S. Army Signal Corps.

R5. Energy Spectra of Secondary Electrons from Mo and W for Low Primary Energies. G. A. HARROWER, *Bell Telephone Laboratories* (introduced by H. D. Hagstrum).—Measurements have been made of the energy spectra of secondary electrons from molybdenum and tungsten, using primary energies Vp, from 0 to 100 volts. A 127° electrostatic analyzer was used having a resolution of one percent. Primary electrons were decelerated to the required energy while approaching the target. The target was cleaned before each measurement by heating above 2000°K for one second. Measurement of the energy spectrum could be completed before formation of the first monolayer of contamination on the target surface. For Vp above 20 volts, the observed energy spectra, each consisting of a low energy maximum and a peak of elastically reflected primary electrons, were almost independent of Vp. For Vp below 20 volts, the low energy maximum became increasingly lower and narrower, and moved upward in energy by approximately 2 volts. For Vp below about 5 volts, reflected primaries remained but secondaries were absent. Similar but not identical results were obtained for both molybdenum and tungsten targets. These observations are consistent with the hypothesis that the initial exchange of energy from primary to secondary electrons occurs nearer the surface of the target as primary energy is decreased.

R6. Transition between Field and Thermionic Emission. E. L. MURPHY AND R. H. GOOD, JR., *Pennsylvania State University.*—Thermionic and field emission from metals are well understood. However, the various types of emission have usually been studied separately by first specifying the range of temperature and field and then constructing the appropriate expression for the current. In the investigations described here, the emission was studied to establish ranges of temperature and field for the two types of emission. A general expression for dependence of emitted current on field and temperature has been found. Each type of emission is then associated with an approximation method and with a resulting dependence on the parameters, ϕ, F, kT. (ϕ is work function, F applied field; Hartree units are used.) Our preliminary results, for substances with high work functions, are: The thermionic region, in which the logarithm of the current, $\ln j$, varies primarily like $-(\phi-F^{\frac{1}{2}})/kT$, applies roughly when $F^{\frac{1}{2}}/kT<\pi/2$. The field emission region, in which $\ln j$ varies primarily like $-2(2\phi)^{\frac{1}{2}}/3F$, applies roughly when $F/\phi^{\frac{1}{2}}kT>6$. Calculations

indicate an intermediate region, in which $\ln j$ varies primarily like $-(\phi/kT)+(F^3/24k^3T^3)$, which applies roughly when $F^{\frac{3}{2}}/kT>\pi$ and $F/\phi^{\frac{1}{2}}kT<3$.

R7. Velocity Distribution in Field Ion Emission. ERWIN W. MÜLLER AND KANWAR BAHADUR, *The Pennsylvania State University.*—Emission of positive ions in an extremely strong electric field can occur by field desorption of absorbed matter,[1] by field evaporation at room temperature of the emitting metal itself, and by field ionization of impinging gas molecules. In the latter case which is being used in the field ion microscope,[2] the currents are measured in a retarding potential tube. Velocity distribution curves as obtained for the rare gases and some molecular gases indicate that the ions originate in a distance of at least 6 to 8 A above the surface, where the ground state of the neutral particle is above the Fermi level inside the metal. In the lower field range where the ionization probability of the approaching molecules is small, the majority of the ions is produced in the same ionization zone after the molecules have bounced back from the metal surface.

[1] E. W. Müller, Naturwiss. **29**, 533 (1941).
[2] E. W. Müller, Z. Physik **131**, 136 (1951).

R8. Field Emission Observations of Phase Transformations in Titanium. E. G. BROCK, *General Electric Research Laboratory.*—Time-lapse movies of field emission microscope patterns from titanium single crystals undergoing phase transformations have been made. The transforming crystals obey the unique orientation relation between the two phases found earlier.[1] The crystals transform over a range of temperatures rather than at a single temperature. It appears possible to super cool the high-temperature phase and superheat the low-temperature phase in any given crystal. Frequently, a pattern which shows part hexagonal-close-packed, part body-centered-cubic symmetry can be stabilized. Both applied field and temperature treatment affect the rate of transformation.

[1] E. G. Brock and J. E. Taylor, Bull. Am. Phys. Soc. **30**, No. 1, 30 (1955).

R9. Thermionic Properties of Thorium on Tungsten Single Crystals.* J. E. DAVEY† AND E. A. COOMES, *University of Notre Dame.*—The effects of adsorption, migration, and evaporation of thin films of thorium on 5-mil single crystal tungsten wire have been studied by thermionic emission measurements. Cylindrical projection tube patterns show that below 1600°K, thorium is strongly adsorbed at grain boundaries, and migration proceeds mostly along grain boundaries. At 1700°K and above, thorium migrates from grain boundaries onto single crystal faces; these faces exhibit preferential adsorption. Emission measurements in a Nichols-Smith[1] type tube show the pattern characterizing thorium on tungsten to have maxima of emission in the (112) and (221) directions and minima in the (114), (111), and (110) directions. Evaporation data indicate that stable emission patterns, with these maxima and minima, may be attained at temperatures as high as 2000°K. When the thorium is flashed off, the (114) and (111) directions become maxima, while the (112), (221), and (110) are minima; this agrees with the pattern for clean tungsten obtained by Nichols and Smith.[1]

* Supported by the U. S. Navy Bureau of Ships.
† Now at the Naval Research Laboratory.
[1] G. F. Smith, Phys. Rev. **94**, 295 (1954).

R10. Reaction between BaO and C. MICHAEL HOCH, *The Ohio State University.*—The heat of formation of BaC_2 was determined by measuring the Ba pressure above BaC_2, using the Knudsen effusion method. The heat of formation of BaC_2 is $\Delta H_{298}^0 = 10.2 \pm 0.3$ kcal/mole. The partial pressure of Ba was measured above $[BaO+BaC_2]$ solutions of various composition, and the CO pressure measured above mixtures of $BaO+C$ containing various amounts of BaC_2. From these data the activity of Ba in dilute $[BaO-BaC_2]$ solutions could be obtained.

R11. Activation Diffusion and Thermionic Emission in Oxide Coated Cathodes. R. W. PETERSON, *University of Minnesota.**—It has been found that Sr evolution rates from oxide coated cathodes can serve as a measure of coating reduction rate. Measurements of Sr evolution and thermionic emission from oxide cathodes on nickels with a single impurity (aluminum) will be presented. An explanation of these results in terms of diffusion theory will be given.

* Supported by the U. S. Navy Bureau of Ships.

R12. Determination of Instantaneous Ba and BaO Evaporation Rates from Thermionic Cathodes.* W. C. RUTLEDGE, *Philips Laboratories.*—In a recent investigation† of the mechanism of operation of Philips dispenser cathodes, the evaporation products were identified as barium and barium oxide, and their evaporation rates were determined as a function of cathode aging time and temperature. The procedure for determining evaporation rates is based upon the well-known method of exposing a clean tungsten wire to a stream of pure barium and noting the time required to reach optimum emission. A similar optimum in the emission-time curve is observed for a stream consisting of a mixture of barium and barium oxide. Chemical calibration of the wire as a detector of *total* barium indicates nearly the same sensitivity for the mixture as for pure barium. By exposing the detector to the evaporant until optimum emission is reached, aging the wire at a temperature sufficiently high to selectively remove free barium, and re-exposing the wire at the original temperature to the evaporant until optimum emission is again attained, the fraction of barium oxide in the mixture may be determined.

* Work supported by U. S. Bureau of Ships contract.
† Rittner, Rutledge, and Ahlert (to be published).

THURSDAY EVENING AT 7:00

King Edward Hotel

(R. T. BIRGE presiding)

Banquet of the American Physical Society

FRIDAY MORNING AT 9:30

McLennan 132

(P. DEMERS presiding)

General Nuclear Physics

S1. (Abstract withdrawn.)

S2. Elastic Scattering of Alpha Particles from Al and Cu.* E. BLEULER AND D. J. TENDAM, *Purdue University.*—The elastic scattering of 19-Mev alpha particles by Al and Cu has been measured in the range from 14° to 144°. The scattered particles were detected with a thin NaI crystal and recorded on a twenty-channel analyzer. The proton background was obtained by differential absorption and subtracted. The ratio of the observed to the Rutherford cross section drops sharply for Al and fluctuates about a mean value of 0.2 for angles larger than 25°. Maxima are observed at 27.5°, 43°, 64°, 87°, and 118°, the peak-to-valley ratios being 2 to 3. For Cu, the cross-section ratio drops from unity at 25° to about 0.02 at 140°. Maxima appear at 60°, 80°, 116°, and about 142°. They are considerably shallower than in the case of Al. Postulating that the difference of $2kR\sin(\varphi/2)$ for neighboring maxima is equal to π, one obtains $R(\mathrm{Al})=5.3_3\times10^{-13}$ cm, and $R(\mathrm{Cu})=6.6_4\times10^{-13}$ cm, compatible with $R=(1.4+1.3\ \mathrm{A}^{\frac{1}{3}})\times10^{-13}$ cm.

* Supported by the U. S. Atomic Energy Commission.

S3. Consistency of Nuclear Radius Determinations from Elastic Scattering of Alphas.* D. D. KERLEE, J. S. BLAIR, AND G. W. FARWELL, *University of Washington.*—The focused external beam of the University of Washington 60-in. cyclotron has been used to extend the earlier measurements of cross section *vs* energy for elastic scattering of alpha particles by heavy nuclei.[1] Observations have been made on Ag, Pb, and U. Angles studied include 41.6, 60, and 90 degrees; energies range from 14 to 44 Mev. All cross section *vs* energy curves have the same general features as those already described.[1] Nuclear radii determined from the one-quarter point criterion of the semiclassical strong absorption model[2] differ very little for various angles of observation; for example, results for Pb at 90 and 41.6 degrees differ by 1 percent, and those for U at 90 and 60 degrees differ by 2 percent. Although the differences are within the limits of experimental error, it may be significant that angles less than 90 degrees give slightly smaller one-quarter point radii, as predicted by the semiclassical strong absorption computations.

* This work was supported in part by the U. S. Atomic Energy commission.
[1] G. W. Farwell and H. E. Wegner, Phys. Rev. **95**, 1212 (1954).
[2] J. S. Blair, Phys. Rev. **95**, 1218 (1954).

S4. The Quenching of the Long Lifetime Component of Positron Annihilation in Benzene.* S. BERKO AND A. J. ZUCHELLI, *University of Virginia.*—The nature of the anomalous lifetime of positron annihilation in solids and liquids is perplexing.[1,2] Pond[3] has found a change in the two-photon annihilation rate in benzene by introducing an organic free radical. We have measured directly the lifetime of positron in benzene as a function of the concentration of the stable free radical diphenyl picryl hydrazyl (DPH), using a Bell and Graham type fast coincidence circuit. The half-life of the τ_2 component in pure benzene is $(1.89\pm0.06)\times10^{-9}$ sec, and quenches to 1.5×10^{-9} sec with 0.1 percent, 1.24×10^{-9} sec with 0.3 percent, 0.85×10^{-9} sec with 0.5 percent DPH. The complete τ_2 *vs* DPH concentration curve will be presented. The quenching cross section as computed from this curve will be discussed in the light of the triplet-singlet conversion theory via electron exchange *vs* the assumption of the formation of $2S$ positronium state.[3] Preliminary results of a quenching experiment via a strong external magnetic field will also be presented.

* Supported by the Office of Ordnance Research.
[1] R. E. Bell and R. L. Graham, Phys. Rev. **90**, 644 (1953).
[2] W. R. Dixon and L. E. H. Trainer, Phys. Rev. **97**, 733 (1955).
[3] T. A. Pond, Phys. Rev. **93**, 478 (1954).

S5. Nuclear Magnetic Resonance Spectrum of Al^{27} in Euclase.† R. G. EADES,* *University of British Columbia* (introduced by Dr. G. M. Volkoff).—The nuclear magnetic resonance spectrum of Al^{27} perturbed by electric quadrupole interaction with its surroundings in a single crystal of $HBeAlSiO_5$ (euclase) was studied in a magnetic field of 7000 gauss. The Al^{27} nuclei are found to occupy two kinds of sites which differ from each other only in the orientation of the principal axes of the electric field gradient tensors whose eigenvalues are all distinct, but identical at the two sites. The absolute value of the quadrupole coupling constant for both groups of Al^{27} nuclei is found to be $|eQ\varphi_{zz}/h|=5173\pm10$ kc, and the axial asymmetry parameter at both sites is $\eta=(\varphi_{xx}-\varphi_{yy})/\varphi_{zz}=0.698\pm0.009$. The two sets of principal axes are reflections of each other in the (010) plane which is consistent with x-ray data for euclase.

† Work supported by grant from National Research Council of Canada.
* Holder of N. R. C. Post-Doctorate Fellowship at University of British Columbia. Now at the University College of North Wales, Bangor, Great Britain.

S6. Direct Polarization of In^{115} Nuclei; J-Value for the 1.458 ev Resonance. J. W. T. DABBS, L. D. ROBERTS, AND S. BERNSTEIN, *Oak Ridge National Laboratory.*—Indium nuclei have been polarized by the direct application of an external magnetic field at a very low temperature. Twenty thin plates of In metal were thermally attached to a paramagnetic salt $(Fe(NH_4)(SO_4)_2\cdot12H_2O)$ which was cooled by adiabatic demagnetization from 0.99°K and 16 400 gauss. After demagnetization, the cooling salt was kept in essentially zero field while 11 150 gauss was slowly applied to the nuclear sample some 12 cm away. The polarization thus produced was measured by determining the change in transmission of the In for polarized 0.075-ev neutrons when the relative spin orientation of the neutrons and nuclei was reversed. The maximum change observed was 7.0 ± 0.9 percent, corresponding to an indium temperature of 0.043 ± 0.005°K, and a nuclear polarization of 2.1 percent. In contrast, at 4.2°K with all other conditions the same, a change of 0.035 ± 0.52 percent was observed. At this temperature, an effect of 0.07 percent is predicted theoretically. The direction of the observed change

establishes the angular momentum of the compound nucleus for the level corresponding to the 1.458-ev resonance in In^{115} as $J = I + \frac{1}{2} = 5$, in disagreement with Brockhouse.[1]

[1] B. N. Brockhouse, Can. J. Phys. **31**, 432 (1953).

S7. Quadrupole Resonances in Multichlorobenzenes. P. J. Bray,*†*Rensselaer Polytechnic Institute*, and R. G. Barnes,† *University of Delaware*.—Chlorine-35 pure quadrupole resonances have been measured in 1,3,5-trichlorobenzene, 1,2,3-trichlorobenzene, 1,2,3,4-tetrachlorobenzene, and pentachlorobenzene. With this and previously published data,[1,2] a plot has been made of frequency *versus* number of chlorine atoms on the benzene ring. This type of plot, first given by Monfils and Duchesne,[1] is now complete except for 1,2,3,5-tetrachlorobenzene. There are *three* distinctly different series of frequencies arising from: nuclei seeing other chlorines only in *meta* and *para* positions; nuclei seeing one of their chlorine neighbors in the *ortho* position; nuclei seeing two chlorines in *ortho* positions. Variation in numbers of *meta* and *para* neighbors causes some scatter about the lines through the latter two series. The effect of the asymmetry parameter variation with type of neighbor (not discussed by Monfils and Duchesne) will be illustrated with *para*- and *ortho*-diiodobenzene. Corrections to computed[1] out-of-plane bending angles of the CCl bonds will be given.

* Research supported by a grant from the National Science Foundation.
† Research supported by the Office of Ordnance Research and the Research Corporation.
[1] A. Monfils and J. Duchesne, J. Chem. Phys. **22**, 1275 (1954).
[2] P. J. Bray, J. Chem. Phys. **23**, 220 (1955).

S8. Evolution of Elemental Abundances Resulting from Neutron Capture in Stars. A. G. W. Cameron, *Chalk River Laboratories*.—Following exhaustion of hydrogen in a stellar core, contraction leads to temperatures at which helium thermonuclear reactions take place, including the $C^{13}(\alpha,n)O^{16}$ reaction.[1] The neutrons are thermalized to about 10 kev and captured by their surroundings. The differential equations describing the resulting evolution of the nuclear abundances have been numerically integrated under the simplification in which substantial ranges of mass number were treated as groups. The abundances of elements heavier than iron rapidly increase by large factors, after which they are relatively insensitive to the number of neutrons injected into the cosmic mixture. The factors range from about 100 in the neighborhood of mass 75 to about 10 000 in the rare earth region. Anomalously large abundances of heavy elements in certain stellar spectra can thus be attributed to a small admixture (2 to 10 percent) of neutron-evolved core material into the surface layers. The amount of C^{13} remaining from the carbon cycle is insufficient to produce the necessary number of neutrons. It is probable that the mechanism which brings core material to the surface also produces additional C^{13} by mixing some envelope hydrogen into the core where it can react with the products of helium thermonuclear reactions.

[1] A. G. W. Cameron, Astrophys. J., **121**, 144 (1955).

S9. Electron Mass as the Natural Unit of Mass for Nuclei and Elementary Particles. Enos E. Witmer, *University of Pennsylvania*.—The mass of any nucleus in any state may be represented by Mm, where m is the rest mass of the electron. Any nuclear excitation energy or reaction energy may be represented in the same way, using the equivalence of mass and energy. Many M-values appear to be astoundingly close to integers and the writer[1] has surmised that M for nuclei and elementary particles is always an integral multiple of 1/256 (except perhaps when the nucleus is in a very highly excited state). New tables make possible a better test of these ideas. From the tables of Ajzenberg and Lauritsen[2] the number of M-values that are integers to within ± 0.025 is about twice that expected by chance. Half-integers are superabundant also. Drummond's[3] table of atomic masses appears to be the best so far. Taking $m = 0.000548770864$ a.m.u. out of 62 accurate M-values there are 6 that are integers to within ± 0.0066. Correction was made for the binding energy of the electrons. The probability of this happening by chance is small.

[1] E. E. Witmer, Phys. Rev. **95**, 667 (1954); **95**, 610 (1954).
[2] F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. **27**, 77 (1955).
[3] J. E. Drummond, Phys. Rev. **97**, 1004 (1955).

Friday Morning at 9:30

Wallberg Building

(G. M. Volkoff presiding)

Theoretical Physics, I

T1. Electron Capture by Positrons in Gases. J. David Jackson, *McGill University*.—Impulse approximation calculations have been made of electron capture by protons and positrons in gases. Previous work for protons and positrons in hydrogen has shown that the impulse approximation gives reasonable values for relative probabilities of capture into various final states but overestimates the absolute cross section by a factor between 5 and 10. The present results for protons in air confirm this behaviour, the computed cross section having roughly the correct energy dependence but being a factor of from 8 to 10 larger than experiment. Nevertheless, it is believed that for high velocities reasonable estimates for electron capture by *positrons* can be obtained by multiplying the ratio of the cross sections computed in the impulse approximation for positrons and for protons of the same velocity by the *observed* cross section for protons. For positrons in air the values (in units of 10^{-17} cm^2) so obtained are:

$(v/v_0)^2$	2.0	2.5	3.0	4.0	6.0	8.0	10.0
σ_{1s}	9.4	10.0	9.3	7.1	3.8	2.2	1.3
σ_{2s}	0.37	0.77	0.86	0.78	0.48	0.29	0.18
σ_{2p}	0.12	0.31	0.38	0.35	0.20	0.10	0.06

Results for positrons in other gases will be presented.

T2. A Quantum Mechanical Calculation on the Stopping Cross Section of Hydrogen Atoms for Protons. A. Dalgarno, *The Queen's University of Belfast* and G. W. Griffing, *Geophysics Research Directorate*.—Considerable theoretical work has been done on the problem of the stopping of heavy positively charged particles passing through matter when the particle energy is sufficiently high so that capture is not an important process.[1] Little quantitative information from a theoretical point of view is available for the lower energies nor has the relative importance of the different modes by

which energy may be lost been investigated. The results to be presented are for the stopping of protons by hydrogen atoms in the energy range between 10 kev and 3 Mev. A comparison with experimental results[2,3] is possible by supposing that a hydrogen molecule is approximately equivalent to two hydrogen atoms. At energies above 100 kev the agreement between theory and experiment is excellent and even for the energy range between 20 and 100 kev the deviation does not exceed 10 percent, the largest deviation being at the maximum of the stopping cross section at about 60 kev.

[1] H. A. Bethe and J. Ashkin, *Experimental Nuclear Physics*, E. Segrè, editor (John Wiley and Sons, Inc., New York, 1953).
[2] J. A. Phillips, Phys. Rev. **90**, 532 (1953).
[3] Reynolds, Dunbar, Wenzel, and Whaling, Phys. Rev. **92**, 742 (1953).

T3. Calculations on Charge Independence with Repulsive Core Potentials.* J. SHAPIRO, *University of Toronto*, AND M. A. PRESTON, *McMaster University*.—Programs, described elsewhere,[1] have been written for Ferut, for low energy $n-p$ and $p-p$ scattering in the ^1S state. The results described in reference 1 have been analyzed further, making rough corrections for (a) magnetic interactions and (b) shape dependence of the experimental parameters. These calculations show that in order to obtain charge independence (a) the potential must be at least as singular as the Yukawa, (b) the core radius required increases with the order of singularity of the potential at small distances (the Yukawa potential is charge independent for zero core), and (c) the experimental results restrict the core radius for a given shape to within very small limits. Results will be given.

* Assisted in part by the National Research Council of Canada.
[1] M. A. Preston and J. Shapiro, Phys. Rev. **96**, 813 (1954).

T4. Deuteron Model Calculation of the High-Energy Nuclear Photoeffect.* K. G. DEDRICK,† *Stanford University*.—The high-energy nuclear photoeffect has been calculated according to the "deuteron model" of Levinger. In this model, the photoprocess occurs when a neutron and a proton, which are scattering one another inside the nucleus, absorb the energy of the incident photon and escape from the nuclear potential well into the laboratory. The nuclear photoeffect cross section is then obtained by averaging the cross section for the above process over all possible neutron-proton pairs in the nucleus, assuming a form for the ground-state nucleon momentum distribution. The electric dipole and quadrupole interactions of the radiation field with the neutron and proton are included and the magnetic terms are neglected. The averaging over all neutron-proton pairs is performed by means of a random flight formulation of the problem. The analytical work involved may conveniently be done using either a zero temperature Fermi ground-state nucleon momentum distribution or a Gaussian distribution. Numerical results for the energy and angle distributions of photoneutrons and photoprotons are presented in the case of the gaussian distribution for four photon energies between 50 and 125 Mev.

* Supported in part by the Office of Scientific Research, Air Research and Development Command.
† Now at Engineering Research Institute, University of Michigan, Ann Arbor, Michigan.

T5. Cascade Transitions between Rotational Levels in Odd A Nuclei.* HANS MARK AND GEORGE PAULISSEN, *MIT*—In several odd A nuclei, it is possible to excite the first two "rotational" levels by electric excitation.[1,2] Using this process and a $\gamma-\gamma$ coincidence spectrometer, the ratio of cascade to crossover γ rays has been measured for several levels in odd A isotopes. Preliminary results are shown in the table. The values of cascade/crossover for Ta^{181} and $Ag^{107,109}$ are in reasonable agreement with results of other workers.[3,4] Other measurements of this type are in progress on a series of isotopes in the region $Z=70$ to 80.

Nuclide	E_1	E_2	Cascade/crossover
$Ag^{107,109}$	315	418	<0.2
Ta^{181}	137	303	1.68 ± 0.42
Re^{187}	139	320	4.74 ± 1.2

* Supported by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] Huus and Zupančič, Danske Math.-fys. Medd. **28**, No. 1 (1953).
[2] McClelland, Mark, and Goodman, Phys. Rev. **97**, 1191 (1955).
[3] Goldburg and Williamson, Phys. Rev. **95**, 767 (1954).
[4] McGowan and Stelson (Private Communication).

T6. On the Theory of Radiative Beta Decay and Electron Capture. F. G. HESS AND W. OPECHOWSKI, *The University of British Columbia*.—Explicit expressions for the probability of some of these effects have been obtained in various approximations. An arbitrary mixture of the five Fermi interactions has been assumed, but the calculations are restricted to allowed transitions. The best approximation considered corresponds to evaluating the contribution of intermediate states with semi-relativistic Coulomb wave functions. For the case of the radiative K-capture, this approximation is probably equivalent to that used by Glauber and Martin.[1] Perhaps the most striking difference (though of not much practical importance) between the case of radiative electron capture and that of radiative beta decay is a quite different dependence of these two effects on the five Fermi interaction constants: when the scalar and tensor interaction constants are respectively equal to the vector and axial interaction constants, the probability of the former effect reaches its minimum value (in fact, it vanishes when one disregards the contribution of the pseudoscalar interaction) while that of the latter effect may be far above its minimum value.

[1] R. J. Glauber and P. C. Martin, Phys. Rev. **95**, 572 (1954).

T7. "Normalized" β Interactions. D. C. PEASLEE, *Purdue University*.—Linear combinations of the five invariants SVTAP are considered as basis vectors for the representations of the three-object permutation group P_3. Orthogonality of the basis vectors implies certain relative magnitudes for the invariants, so that the basis vectors can be "normalized." In terms of a previous notation[1] they are Ω_1, Ω_4, Ω_5, $(S-A-P)$, and $[(2(S+P)+A]-3V$, with respective normalizing factors $8^{-\frac{1}{2}}$, $16^{-\frac{1}{2}}$, $24^{-\frac{1}{2}}$, $6^{-\frac{1}{2}}$, $48^{-\frac{1}{2}}$. Each normalized combination yields the same μ decay lifetime for a given strength of the coupling constant. The criterion of invariance under "mass reversal" did not discriminate between the previous Ω_1 and Ω_2; in combination with antisymmetry under Fierz exchange it now uniquely selects $(S-T+P)$.

[1] D. C. Peaslee, Phys. Rev. **91**, 1447 (1953).

T8. The Coupling Constants of the Beta-Decay Interaction and the Decay of Rb^{87}. M. A. PRESTON, *McMaster University*.—The third forbidden shape of the beta spectrum of Rb^{87} has been analyzed on the assumption that the lepton-nucleon interaction is an S, T mixture. Although accurate numerical values of the ratio g_S/g_T can not be found in this way, it is believed that the experimental data provide evidence that the sign of the ratio is positive. The absolute value of the ratio is consistent with the O^{14}, H^3, and neutron decay constants.

T9. Analysis of Triple Angular Correlations in Nuclear Bombardment Experiments. A. J. FERGUSON AND A. E. LITHERLAND, *Chalk River Laboratories*.—A triple angular correlation can be expanded in terms of associated Legendre polynomials and trigonometric functions of the polar angles of the second radiation and the colatitude of the third radiation, the coordinate axis being taken in the direction of the incoming radiation. Using punched card machines and the formulation of Sharp *et al.*,[1] the coefficients for this expansion have been calculated for the case of an incoming particle followed by two

gamma rays for ranges of quantum numbers sufficient to interpret many experiments. The theoretical results for particular experimental arrangements, e.g., when one counter is fixed and the other is moved in a plane, are easily obtained from the coefficients. Some of the coefficients are determined by the correlation of the incoming particle with the first gamma ray, the second being unobserved, and also with the second gamma ray, the first being unobserved. Generally there are other coefficients not determined by these simple experiments which require a triple correlation experiment. In such cases additional information is available which may be necessary to determine such quantities as spins and multipole mixtures.

[1] Atomic Energy of Canada Limited Report CRT-556 (unpublished).

T10. The Possibility of a Nuclear Change of Phase. L. E. H. TRAINOR AND W. R. DIXON,* *Queen's University.*—Lang and LeCouteur[1] have shown that the nuclear model of a degenerate Fermi gas, whose greatest merit is simplicity, yields a level density formula which may be considered satisfactory for nuclear excitations above 10 Mev. Livesey[2] has recently suggested that considerable experimental data are consistent with the hypothesis that the nuclear temperature is effectively constant below 10 Mev. Despite obvious limitations to such considerations, it appears fruitful to extend the usual thermodynamical description to interpret Livesey's observation as indicative of a first-order nuclear phase change in which the energy, entropy, and volume are altered with little or no change in temperature and pressure. This interpretation appears to be consistent with some other points of view regarding nuclear structure. Its validity and consequences are under investigation.

* Now at National Research Council of Canada.
[1] Lang and LeCouteur, Proc. Phys. Soc. (London) A67, 586 (1954).
[2] D. L. Livesey, Can. J. Phys. (to be published).

FRIDAY MORNING AT 9:30

McLennan 135

(G. M. SHRUM presiding)

Semiconductors

U1. Pressure Dependence of the Resistivity, Hall Constant, and Energy Gap for InAs* (Author unknown).—The effect of pressure on the resistivity of intrinsic n-type InAs has been measured in the range from 1 to 2000 atmospheres. The resistivity and the Hall constant increase exponentially with increasing pressure. Measurements of the resistivity and Hall effect indicate an increase of 20 and 8 percent respectively for a change in pressure of 2000 atmospheres. If it is assumed the increase in resistivity is produced by an increase in the energy gap our measurements indicate a shift of 10.5 $(10)^{-6}$ ev/atmosphere. The increase in Hall constant represents a shift of about $4(10)^{-6}$ ev/atmosphere.

* Work supported by the Office of Ordnance Research.

U2. Surface Levels, Their Influence on the Field Effect and $1/f$ Noise. S. R. MORRISON, *Sylvania Electric Products Inc.*—We have studied at low temperatures the properties of the long time constant levels on the germanium surface using the dc field effect, illumination, and heating to stimulate transitions between these levels and the bulk germanium. It is shown that the decay of an excess surface conductance arising as these levels are depopulated can be described by the relation

$$1-\exp\beta\Delta\sigma = A\exp(-\gamma t),$$

where β and γ depend on the properties of the material and on temperature, A depends on the initial condition. This relation is derived on the basis of a potential barrier (surface barrier) which restricts electron transfer. The important property of this barrier is that a small change in the charge on the levels produces a proportional small change in the height of the barrier. This would be expected for agglomerates, lines (edge dislocations) or planes (surface) of levels. The analysis of this type of level shows agreement with the log$f$ dependance observed by Kingston for the ac field effect. The role of this trap type in $1/f$ noise will be discussed.

U3. Elasto-Galvanomagnetic Effect in Germanium. ROBERT W. KEYES, *Westinghouse Research Laboratories.*—The work of Smith[1] and Herring[2] has shown that the transport properties of an elastically strained semiconductor are sensitive to details of the energy band structure and scattering processes not revealed by study of the ordinary transport properties. A macroscopic theory shows that in a cubic crystal four coefficients are required to describe the terms in the conductivity tensor which are linear in both the magnetic field and the strain. A detailed theory shows that only one of these, a shear coefficient is large in a semiconductor with energy minima in the (111) directions in k space. Measurements of the Hall effect in elastically strained N-type germanium are in accord with this model of the energy surface, and show that the contribution of inter-valley scattering to the effects is small at 25°C. Since inter-valley scattering should be appreciably changed by the strain, we conclude that it is only a small part of the total scattering at the temperatures in question.

[1] C. S. Smith, Phys. Rev. **94**, 42 (1954).
[2] C. Herring, Bell System Tech. J. **34**, 237 (1955).

U4. Galvanomagnetic Theory of N-Germanium and Silicon in the Saturation Limit.* LOUIS GOLD AND LAURA M. ROTH, *Lincoln Laboratory.*—A tensor formalism has been found effective for dealing with the galvanomagnetic properties of the 8−[111] and 6−[100] ellipsoidal models of the energy surfaces; the treatment is based upon the simplifying assumption of energy independent scattering time τ. Conductivity tensors are obtained starting with the phenomenological equations of motion. Contributions from the multifold energy surfaces are combined after a suitable spatial transformation which refers these to a common axial system—the crystal axes—to yield the over-all conductivity tensor. However, for the magnetoresistance $\Delta\rho/\rho$ and the Hall coefficient the inverse tensor is required and here the analysis becomes encumbered with algebraic detail. The problem is considerably more amenable in the saturation limit, i.e., high magnetic fields, or more generally $\omega\tau\gg 1$ where we define $\omega = qB/m^*\cdot 3K/2K+1$. m^* is the average effective mobility mass and $K>1$ the axial ratio of mass tensor components related to the ellipsoidal energy surfaces. Explicit expressions for $\Delta\rho/\rho$ have been derived for a number of orientations of the current density and magnetic field and an evaluation in terms of extant theory and experiment has been made.

* The research reported in this document was supported jointly by the Army, the Navy, and the Air Force, under contract with Massachusetts Institute of Technology.

U5. Galvanomagnetic Theory of Holes in Germanium and Silicon.* J. G. MAVROIDES AND BENJAMIN LAX, *Lincoln Laboratory.*—Using the results of the Boltzmann transport theory for weak magnetic fields[1] and assuming warped spherical energy surfaces in **k** space, expressions for the conductivity, Hall constant, and magnetoresistance have been obtained. The method involves a series expansion in which only a finite number terms are required to evaluate the density of states, conductivity, Hall constant and magnetoresistance. The scheme is applicable for any energy dependence of the relaxation time. Results have been obtained assuming that the relaxation time $\tau = l\mathcal{E}^{-p}$, where l is a temperature dependent coefficient, $\mathcal{E}$ is the energy, and p is a suitable parameter which takes on values depending on the type of scattering. Using cyclotron resonance data the results are applied to the interpretation of directional magnetoresistance effects in germanium[2] and silicon.[3] The expansion method is being extended to the limit of high fields where the Boltzmann transport equation has been solved as a series expansion in $1/H$.

* The research reported in this document was supported jointly by the Army, the Navy, and the Air Force under contract with Massachusetts Institute of Technology.
[1] B. Abeles and S. Meiboom, Phys. Rev. **95**, 31 (1954).
[2] G. L. Pearson and H. Suhl, Phys. Rev. **83**, 768 (1951).
[3] G. L. Pearson and C. Herring, Physica **20**, No. 11, 975 (1954).

U6. Nature of the Water Vapor Induced Excess Current on Germanium $P-N$ Junctions. EDWARD N. CLARKE, *Sylvania Electric Products Inc.*—Studies have been made to determine the nature (ionic or electronic) of water vapor induced excess current on grown germanium $P-N$ junctions by examining the reverse current-voltage characteristic over the range 0.01 to 16 volts. It appears that the nature of the current depends upon the voltage and upon the surface treatment prior to the measurement. The excess currents on a fresh, well etched surface are smaller and have voltage relationships suggesting that sometimes the current is ionic and sometimes electronic. Less well-etched surfaces show larger excess currents which may be ionic at low voltages, becoming electronic at higher voltages (greater than 0.1 to 1.0 volt). The higher voltage currents rise more rapidly with increasing voltage than predicted by "channel" theory.[1] This more rapid increase with increasing voltage can be made even greater by mechanically disturbing some of the surface near the junction on the p-type side (reverse current in vacuum not greatly altered). The effects observed may result from the presence of dislocations in the disturbed region. The presence of dislocations near a surface may help to explain the lack of complete agreement between observed "channels" and "channel" theory at higher voltages.

[1] A. L. McWhorter and R. H. Kingston, Proc. Inst. Radio Engrs. **42**, 1376 (1954).

U7. New Intrinsic Recombination Radiation from Germanium. J. R. HAYNES, *Bell Telephone Laboratories, Inc.*—Intrinsic radiation from germanium due to recombination of injected holes and electrons has been reported by Haynes and Briggs[1] and by Newman.[2] The results of these investigations show that this radiation from relatively thick specimens has a single maximum which occurs at a wavelength of about 1.8μ. Recent results obtained using radiation from very thin germanium sections (in order to reduce optical absorption) show that additional radiation is produced by a different recombination mechanism resulting in a second maximum at 1.5μ. This result is in accord with the optical absorption data of Dash, Newman, and Taft[3] and the detailed balance analysis of van Roosbroeck and Shockley.[4]

[1] J. R. Haynes and H. B. Briggs, Phys. Rev. **86**, 647 (1952).
[2] Roger Newman, Phys. Rev. **91**, 1313 (1953).
[3] Dash, Newman, and Taft, Bull. Am. Phys. Soc. **30**, No. 1, 53 (1955).
[4] W. van Roosbroeck and W. Shockley, Phys. Rev. **94**, 1558 (1954).

U8. Noise Characteristics of Silicon Photovoltaic Junctions. U. F. GIANOLA, *Bell Telephone Laboratories.*—The noise spectrum associated with the photovoltaic voltage in large area silicon $p-n$ junctions has been measured for zero bias conditions. These junctions were prepared by gaseous diffusion and the p-layers are about 0.0001 inch thick. It is found that the noise power at a given illumination has a $1/F$ frequency dependence at low frequencies, and that its maximum value at 20 cy/sec is $\sim 10^4$ times larger than expected from shot noise. At higher frequencies the reactive component of the dynamic barrier impedance becomes important, and the noise power decreases more rapidly with increasing frequency. The noise voltage passes through a maximum at an illumination in the region of four foot candles, and is reproduced by the noise voltage which appears for zero illumination when an external current is inserted. The noise voltage is proportional to $I_p^{\frac{1}{2}}$ and $I_p^{-\frac{1}{2}}$ at low and high illuminations respectively, where I_p represents primary photocurrent. These effects are explained by reference to the equivalent circuit of a photovoltaic junction. These results do not contradict those reported recently[1] because of differences in the geometry and the condition of the surface of the cells measured.

[1] Pearson, Montgomery, and Feldmann, Bull. Am. Phys. Soc. **30**, No. 2, 44 (1955).

U9. Electrical Properties of Thin Film Semiconductors. F. S. HAM* AND D. MATTIS, *University of Illinois.*—The theory of the electrical conductivity and Hall effect for thin metallic films as given by Fuchs and Sondheimer[1] is extended to the case of a nondegenerate semiconductor with ellipsoidal energy surfaces. A change of variable reduces the problem to an equivalent and mathematically simpler one with spherical surfaces. The resulting conductivity decreases with decreasing film thickness as in the case of a metal, but the ellipsoidal energy surfaces make the conductivity differ by as much as a factor of two or more for different orientations of the normal to the film and the current direction with respect to the crystallographic axes. A similar anisotropy is found for the Hall constant and also for the conductivity of a surface layer or "channel" when Schrieffer's theory[2] is generalized to ellipsoidal surfaces. For thin channels or very thin films the anisotropy in the conductivity in the plane of the film is a function only of the ratio of the effective mass components and appears to provide a practical means of measuring this ratio directly if the general features of the band structure are known.

* NRC Fellow, 1954–1955.
[1] E. H. Sondheimer, Advances in Phys. **1**, 11 (1952).
[2] J. R. Schrieffer, Phys. Rev. **97**, 641 (1955).

U10. Electric Conductivity of Composite Media.* EDWARD H. KERNER, *University of Buffalo.*—In a composite medium having any number of isotropic components distributed spatially at random, e.g., as packed or suspended granules, it may be shown from first principles that the gross conductivity is governed by

$$\sigma_0 = \Sigma \sigma_i v_i (\bar{E}_{iz}/\bar{E}_{0z}), \quad 1 = \Sigma v_i (\bar{E}_{iz}/\bar{E}_{0z})$$

where σ_i are the component conductivities, v_i their volume fractions, and $\bar{E}_{iz}, \bar{E}_{0z}$ are average values, in component i and in the whole composite, of the z-component of the electric field produced in the composite when a slab of it is sandwiched between slabs of a uniform medium and a field perpendicular to the slabs (i.e., the z-direction) is turned on. The "intensity factors" $\bar{E}_{iz}/\bar{E}_{0z}$ contain σ_0 in general and may be evaluated in important special cases by an averaging process introduced by Landauer. Illustrative results for packed or suspended granules, either simple or coated (e.g., oxide coated metallic grains), will be given. A case of gross anisotropy, and the extension of the methods to deducing elastic properties of composites, will be discussed.

* Work performed in part under the auspices of the U. S. Atomic Energy Commission.

U11. Noise Fluctuations and Irreversible Processes.* D. L. FALKOFF, *Brandeis University and Lincoln Laboratory.*—Onsager and Machlup have derived an extension of Boltzmann's principle for fluctuations in irreversible processes in which the probability for a temporal sequence of fluctuations in a set of thermodynamic variables is related to the entropy production. Their method is here applied to the case of noise voltage fluctuations in an arbitrary linear passive electrical network in which each resistor is assumed to have a white Gaussian noise output (Nyquist). The conditional probability for the currents at any later time, having specified them at an earlier time, is then exhibited in terms of the appropriate entropy and dissipation functions for the electrical network. Applications to the case of nonreciprocal network elements are also discussed.

* The research reported in this document was supported jointly by the Department of the Army, the Department of Navy, and the Department of the Air Force.

U12. Sensitivity of Radiation Damage to the Displacement Probability. JOHN B. SAMPSON, H. HURWITZ, JR., AND E. F. CLANCY, *Knolls Atomic Power Laboratory.**—In estimating the number of displacements produced in ratiation damage, it is customarily assumed that an atom which receives energy greater than a threshold energy E_d is displaced from its lattice site. It has been then derived[1] that $E_0/2E_d$ displacements are produced by a recoil atom having energy E_0, provided E_0 is below the region where ionization is important. To ascertain the reliability of this estimate, a simplified model has been investigated in which the probability that a struck atom will be displaced is taken to be a linear function of the energy received between E_d and energy $E_1(E_1>E_d)$ at which the probability becomes unity. It is found that the number of displacements is reduced and furthermore that the number depends more sensitively upon E_1 then upon E_d. The reduction may explain a discrepancy pointed out by Harrison and Seitz.[2] This study indicates the importance of a detailed knowledge of the displacement probability if quantitative comparison with experiment is attempted.

* The Knolls Atomic Power Laboratory is operated by the General Electric Company for the U. S. Atomic Energy Commission under Contract No. W-31-109 Eng-52.

[1] W. S. Snyder and J. Neufeld, Phys. Rev. **94**, 760(A) (1954).
[2] W. A. Harrison and Frederick Seitz, Bull. Am. Phys. Soc. **30**, No. 2 (1955).

FRIDAY MORNING AT 9:30

Mechanical Building

(W. P. ALLIS presiding)

Gaseous Electronics and Atomic Physics, I

Invited Paper

V1. Research in Gaseous Electronics in the United Kingdom. H. S. W. MASSEY, *University College, London,* (40 min.)

Contributed Papers

V2. Threshold for Photodetachment from OH^-. S. J. SMITH AND L. M. BRANSCOMB, *National Bureau of Standards.*—The photodetachment from a beam of OH^- has been studied in the spectral range from 4000 to 8000 A. The dependence of the total detached electron current on the spectral distribution of incident photons was observed by the use of sharp cut-off red transmitting filters. The ions are extracted from the anode of a low pressure ($\sim$100 μ Hg) glow discharge using pure water vapor. A mass spectrograph scan shows negative ion impurities present in the beam are less than 5 percent of the OH^- current. The observed threshold for photodetachment lies at about 7000 A (1.75 ev), and the cross section appears to rise rapidly from threshold. The possibility that the threshold is the vertical detachment energy from the ground state of OH^-, and the relationship of this threshold to the OH affinity will be discussed.

V3. Doppler Broadening of Spectral Lines Emitted During Dissociative Recombination. WILLIAM A. ROGERS AND MANFRED A. BIONDI, *Westinghouse Research Laboratories.*—In an earlier paper,[1] a procedure was described for determining whether the large electron-ion recombination observed in microwave afterglow studies results from the process of dissociative recombination. It was pointed out that a characteristic feature of the process is that the excited atoms formed during recombination receive the kinetic energy of dissociation and, therefore, the lines emitted should be Doppler broadened in excess of the thermal width. In order to study the widths of the recombination lines, we have developed a high-sensitivity, direct-recording Fabry-Perot interferometer which uses a photomultiplier as a detector and can trace the shape of an afterglow line in ten minutes. It is found that the 5876 A line of the helium afterglow is considerably broader than the normal thermal width. The observed line width corresponds to an excited atom kinetic energy of $\sim$0.1 ev. Since it is estimated that dissociative recombination in helium would lead to just such excited atom energies, the present result provides strong evidence that this process is responsible for the large electron-ion recombination observed in afterglows.

[1] M. A. Biondi, Phys. Rev. **93**, 650(A) (1954).

V4. Absorption Studies of the Metastable States of Neon. A. V. PHELPS, *Westinghouse Research Laboratories.*—Time sampling techniques have been applied to measurement of the time variation of the absorption of light by neon atoms in the $2p^53s$ configuration following a pulsed discharge. The data are analyzed by comparing terms in the differential equations governing the time variation of the densities of the various excited states. These studies have yielded values for the diffusion and three body destruction coefficients for the $^3P_2$ state and for the probability for the excitation of atoms in the $^3P_2$ state to the $^3P_1$ state as the result of a collision with neutral atoms. These experiments show that at 300°K the destruction of $^3P_2$ metastables as the result of excitation to the $^3P_1$ state is limited by the rate at which the imprisoned resonance radiation can escape from the absorption cell. This effect

accounts for the nonintegral powers of pressure appearing in empirical expressions for the pressure variation of the measured lifetimes of the $^3P_2$ metastable state.[1]

[1] F. A. Grant, Phys. Rev. **84**, 844 (1951).

V5. Nuclear Coincidence Techniques Applied to Optical Transitions. ERIC BRANNEN, F. R. HUNT, R. H. ADLINGTON, AND R. W. NICHOLLS, *University of Western Ontario.*—The complete adoption of the methods of nuclear physics to the study of optical cascade transitions has numerous advantages not found in other methods.[1,2] Steady sources can be used when measuring lifetimes of states. Absolute source strengths and absolute efficiencies of the detection apparatus can be measured directly, as can angular correlation between directions of photons emitted in cascade. Preliminary experimental results employing 1P21 Photomultipliers and a coincidence circuit[3] with a resolving time of $2\tau = 8.6 \times 10^{-9}$ sec will be presented. A mean life of $1.12 \pm 0.02 \times 10^{-8}$ sec was found for the $7\,^1S_1$ state of mercury using interference filters to select the appropriate cascade transitions. This work is supported by the Air Force Cambridge Research Centre, Cambridge, Massachusetts.

[1] Heron, *et al.*, Nature **174**, 564 (1954).
[2] Brannen, *et al.*, Nature (to be published).
[3] Bell, Graham, and Petch, Can. J. Phys. **30**, 35 (1952).

V6. Inelastic Molecular Collisions near the Threshold. B. WIDOM, *Cornell University.*—It is shown that because of the uncertainty principle the probability that a molecular collision be inelastic vanishes at the threshold, in distinction to its classical behavior. This is a consequence of the relation $l + \frac{1}{2} = bk$, where l is the quantum number of the relative angular momentum of the colliding particles, k is the wave number of the relative translational motion, and b is the impact parameter. The inelastic collision probability takes the form

$$k^{2l+1}(c_0 + c_2k^2 + c_4k^4 + \cdots),$$

where k refers to either the incident or emergent wave and l is the corresponding angular momentum quantum number. The first term is the same as that obtained by Wigner.[1] In chemical kinetics this series implies a pre-exponential factor which contains only integral powers of the temperature, whereas $T^{\frac{1}{2}}$ is the usual classical behavior.

[1] E. P. Wigner, Phys. Rev. **73**, 1002 (1948).

V7. The Temperature Dependence of Ionic Mobilities: He^+ and He_2^+ in Helium. LORNE M. CHANIN AND MANFRED A. BIONDI, *Westinghouse Research Laboratories.*—The mobility tube used to determine the drift velocity of near-thermal ions[1] has been modified to permit immersion in refrigerating liquid nitrogen, dry ice) baths. Measurements have been made of the mobilities of He^+ and He_2^+ in helium at 77°, 195°, and 300°K. It is found that the measured mobilities of He_2^+ *vs* temperature are in agreement with the experimental values of Tyndall and Pearce,[2] who mistakenly identified the ion as He^+. Our measured values for He^+ in helium have been compared with the mobilities calculated following the procedure given by Holstein.[3] The measured mobilities are 15 percent lower than the thoretical values $\mu_0 = 17.5$ cm²/volt-sec (77°), 13.8 (195°), and 12.1 (300°).

[1] M. A. Biondi and L. M. Chanin, Phys. Rev. **94**, 910 (1954).
[2] A. M. Tyndall and A. F. Pearce, Proc. Roy. Soc. (London) **A149**, 426 (1935).
[3] T. Holstein, J. Phys. Chem. **56**, 832 (1952).

V8. Ambipolar Diffusion in Xenon at 3-cm Wavelength. R. L. FEY AND W. J. GRAHAM, *Naval Research Laboratory.*—Measurements have been made of the decay of electron density as a function of pressure in the afterglow of a pulsed discharge in xenon at 3 cm wavelength. Techniques used were similar to those used by Biondi and Brown[1] in helium at 10 cm. Experiments were conducted in an Alpert type vacuum system with an ultimate vacuum of about 10^{-10} mm Hg. Results for the ambipolar diffusion constant Da, yield a value $Dap = 24.8$ (cm²/sec) mm Hg ±5 percent at 300°K. Applying the Einstein relation and assuming complete thermal contact in the plasma, this measured value of Dap yields a value for the mobility of Xe^+ in Xe of 0.59 (cm²/volt sec) as compared with 0.58 measured by Biondi and Chanin[2] (values are for 300°K and density of 2.69×10^{19} cm^{-3}). Diffusion cooling effects were found at pressures below about 0.4 mm Hg. Measurements made in helium agreed within experimental error with previous data[1,3] for both atomic and molecular ions.

[1] M. A. Biondi and S. C. Brown, Phys. Rev. **75**, 1700 (1949).
[2] M. A. Biondi and L. M. Chanin, Phys. Rev. **94**, 910 (1954).
[3] A. M. Tyndall and C. F. Powell, Proc. Roy. Soc. (London) **A134**, 125 (1931).

FRIDAY AFTERNOON AT 2:00

McLennan 132

(J. D. JACKSON presiding)

Theoretical Physics, II

Contributed Papers

W1. On The Reciprocity Theory of Elementary Particles. P. H. FANG, *Philco Corporation.*—The reciprocity theory proposes that the Hamiltonian of a system of elementary particles is the eigenfunction of a reciprocity invariant operator. From group theoretical requirement of completeness, it is natural to generalize the invariance of the operator to l-variance, where $l^4 = 1$ (4 is the periodicity of Fourier transform). In this way Born's reciprocity condition becomes the same as the Fourier reciprocity condition. For further generalization, one can treat the space time operators and their conjugate momenta operators as 8-variables and discuss, in the case of scalar and pseudo scalar field, a bilinear form and in the case of spinor, a linear form in such a space. If the eigenfunction is interpreted as Hamiltonians, then there is nondefinite energy state, and, if it is interpreted as the usual wave function, then one meets nondefinite character of the metric form. Therefore, subsidiary conditions have to be introduced in both cases which are not necessarily based on reciprocity and should be contributed to the intrinsic properties of the physical entity in contradistinct to pure geometry. In this way, one arrives at some eigenvalues with dimensions of mass in product form of Klein-Gordon equation and can be compared with the known masses of elementary particles. Finally, one can treat the interaction of this *complete system* of elementary particles of different spins and masses.

W2. Simple Model of Elementary Particles. F. A. KAEMPFFER, *University of British Columbia.*—It is assumed that different elementary particles can be pictured as different self-maintained excitations of a single medium described in terms of a complex scalar function and the electromagnetic potentials. The equations governing the dynamics of the all pervading medium are taken to be the nonrelativistic Schroedinger equation and Maxwell's equations with the wave-mechanical current as source of the electromagnetic potentials. Solutions of this nonlinear simultaneous system of equations are called "particles," provided some reasonable boundary conditions are satisfied. These solutions are the wave-mechanical analog of the solutions of Buneman's[1] self-consistent classical electrodynamics, and of Wheeler's[2] geons. One can grasp within the framework of this model particles carrying charge and magnetic moment, neutral particles carrying magnetic moment, unstable particles, and particles that possess excited states. The model can easily be extended so that the formulation becomes relativistically invariant. The fundamental equations can also be derived from a single gauge invariant action principle.

[1] O. Buneman, Proc. Cambridge Phil. Soc. **50**, 77 (1954).
[2] J. A. Wheeler, Phys. Rev. **97**, 511 (1955).

W3. On the Bloembergen Spin Reservoir Temperature in Paramagnetic Resonance Experiments. J. H. VAN VLECK, *Harvard University.*—Bloembergen and Wang[1] suggested that, in certain salts, *viz.*, those with large exchange coupling, the distribution of exchange energy corresponds to a different temperature than does that of the Zeeman energy. They also indicated that sometimes the transfer of energy between Zeeman components and lattice phonons takes place via the intermediary of the exchange energy rather than directly, and that then the bottleneck associated with the characteristic time T_1 in resonance experiments may relate to the transfer of Zeeman into exchange energy rather than to spin-lattice transfer. In this thesis (p. 40), Bloembergen demonstrated that for a free atom the absorption of energy by the different Zeeman states is such that thermal equilibrium among them is maintained and there is merely a change in the "Zeeman temperature." The present paper points out that this property is preserved even if the atoms have exchange coupling (provided isotropic). Absorption then alters the Zeeman temperature and leaves invariant the temperature of the exchange energy, which consequently serves as a reservoir. The concept of two separate, well-defined Zeeman and exchange temperatures is hence more quantitative and less purely heuristic than implied by Bloembergen and Wang. The exactness of the definition is spoiled when there are crystalline field splittings or appreciable dipolar interactions.

[1] N. Bloembergen and S. Wang, Phys. Rev. **93**, 77 (1954).

W4. On the Invariant Relationship of the Energy-Density and Momentum-Density of the Electromagnetic Field. N. L. BALAZS, *American Optical Company.*—It is well known that W^2-S^2 is an invariant (W=energy density, S=momentum density of the electromagnetic field). This is rather surprising on two counts: (1) its seeming isolation; (2) W, S are components of a tensor, and so, in general, have no right to transform among themselves. In this note we show that the above invariance relationship is one out of the 16 relationships which express that the square of the mixed matrix representing the energy-momentum tensor is in multiple of unity. (In fact in our case one can show that the energy-momentum tensor is, on account of symmetry, its own reciprocal.)

W5. Energy Levels of H^-. L. LEVITT AND G. E. TAUBER, *Western Reserve University,* AND T. Y. WU, *National Research Council, Ottawa.*—The ground-state energy level of the negative hydrogen ion has been determined by the Ritz variational method. It has been found that the presence of terms with fractional powers in the Hylleraas type wave function gave a better value for the energy than those obtained so far.[1] For a 9-parameter wave function of the form

$$\Phi=\exp(-\tfrac{1}{2}ks)[1+c_2u^2+c_3t^2+c_4s^1+c_5u+c_6ut^2 +c_7s+c_8u^3+c_9(u/s)^1].$$

The energy was found to be of the order of -0.539 atomic units as compared with -0.529 atomic units for an 11th order wave function using only integral powers of s, t, u.

[1] S. Chandrasekhar, Revs. Modern Phys. **16**, 301 (1947).

W6. Simplification in Finding Symmetry-Adapted Eigenstates.* M. A. MELVIN, *The Florida State University.*—The method of finding symmetry-adapted functions belonging to irreducible representations of a group is examined. It is shown that for degenerate representations the problem may sometimes be simplified to that for the representations of a subgroup of the original group. Sufficient and necessary conditions for symmetry-adapted function (SAF) simplification are given, and all of the point symmetry groups are examined from this point of view. All of the dihedral-type groups, the tetrahedral group T, and the didodecahedral group T^h, respectively, admit of row-independent simplification in the finding of SAF's belonging to their degenerate representations. For the dihedral-type groups, the problem is simplified to their cyclic subgroups of index 2. By an equivalence transformation, a real form of the E representations of all dihedral-type groups is obtained; this permits of real SAF simplification in all groups with principal axis of order four. For T the problem is simplified to its subgroup of index 3, V. And for T^h, the simplification is to V^h.

* Assisted by a contract with the U. S. Atomic Energy Commission, and by a grant from the Research Council of The Florida State University.

FRIDAY AFTERNOON AT 2:00

McLennan 135

(A. SCHAWLOW presiding)

Cryogenics

Invited Paper

X1. The Viscosity of Liquid Helium II. A. C. H. HALLETT, *University of Toronto.* (30 min.)

X2. Lambda-Point Transition in Relation to Atomic Distribution in Liquid Helium. JAMES REEKIE, *Department of Mines.* (30 min.)

Contributed Papers

X3. Damping of Oscillations of a Sphere by Liquid Helium II at Large Amplitudes. C. B. BENSON AND A. C. H. HALLETT. —Observations have been made of the damping of torsional oscillations of a sphere suspended in liquid helium II while the amplitude of oscillation decayed from 10 to 0.05 radian. From 0.05 radian up to a certain critical amplitude, ϕ_c, the damping is independent of amplitude and corresponds to viscous dissipation in the normal component of helium II. The value of $\phi_c \sim 3\times10^{-1}$ radian but decreases with decreasing temperature and increases roughly as the square root of the period of oscillation. Above ϕ_c the damping increases with amplitude, rapidly at first, but after the amplitude exceeds another critical value, ϕ_l, it increases linearly with amplitude. $\phi_l \sim 2$ radians and is almost independent of temperature. Such a linear dependence of damping on amplitude is consistent with the introduction into the differential equation of the motion of the sphere, of a frictional term proportional to the square of the velocity which is characteristic of turbulence. Near the lambda point there is also a region immediately below ϕ_l in which the damping is independent of amplitude, but has a value larger than the normal component viscous damping.

X4. The Dependence of the Superconducting Transition on Measuring Current. D. C. BAIRD, *The Royal Military College of Canada.*—The superconducting transition in tin has been studied by continuous recording of the resistance as the temperature is lowered. Measuring currents ranging from 1 to 600 ma have been used. The specimens used were polycrystalline wires and so a transition temperature was defined as the temperature at which the resistance had half its full value. It was found that this transition temperature T_i depended upon current i according to $T_i = \text{const}\ i^3$. This is in contradiction to the result deduced for these circumstances from the London model of a current-carrying superconductor.

X5. Specific Heat of Vanadium in the Normal and Superconducting States. C. B. SATTERTHWAITE, W. S. CORAK, B. B. GOODMAN, AND AARON WEXLER, *Westinghouse Research Laboratories.*—Measurements[1] on the specific heat of superconducting vanadium, which revealed an exponential temperature dependence of the electronic specific heat, have been extended to the normal state. After corrections to the 1948 temperature scale had been made, the normal-state specific heat could be represented by $C=\gamma T+[12\pi^4(R/5)](T/\Theta)^3$, with $\gamma=9.26\pm0.03\times10^{-3}$ joule mole^{-1} deg^{-2} and $\Theta=338\pm5$°K. The entropy difference, S_N-S_s, between the normal and superconducting states, extrapolated to 0°K, was found to vanish, in accordance with the third law of thermodynamics. The critical field values deduced from S_N-S_s gave $H_0=1310$ gauss; at higher temperatures they were in agreement with the initial penetration fields previously reported.[2]

[1] Corak, Goodman, Satterthwaite, and Wexler, Phys. Rev. **96**, 1442 (1954).
[2] Aaron Wexler and William S. Corak, Phys. Rev. **85**, 85 (1952).

X6. Atomic Heat of Tin in the Normal and Superconducting States. W. S. CORAK AND C. B. SATTERTHWAITE, *Westinghouse Research Laboratories.*—The atomic heat of tin was measured through the temperature range 1.1–4.5°K in the normal and superconducting states in order to study the temperature dependence of the electronic specific heat in the superconducting state. The higher degree of accuracy of the present work makes possible a more definitive analysis of this property than was possible from existing data.[1] Over a large part of the temperature range studied, the electronic specific heat in the superconducting state could be well represented by an exponential expression in $1/T$ similar to that found in superconducting vanadium.[2] In the normal state, variation of the Debye characteristic temperature with temperature was observed as low as 3°K. The critical field-temperature relationship has been deduced from the difference in entropy between the normal and superconducting states and has been compared with those determined from magnetic measurements.

[1] W. H. Keeson and P. H. Van Lear, Physica **5**, 193 (1938).
[2] Corak, Goodman, Satterthwaite, and Wexler, Phys. Rev. **96**, 1442 (1954).

X7. (Abstract withdrawn.)

X8. On the Orientational Transitions in CD_4. T. A. KEENAN AND H. M. JAMES, *Purdue University.*—CD_4 shows successive orientational transitions at 22.2°K and 27.1°K. To gain an understanding of their origin, we have considered an analogous system of classical spherical rotators arranged in a cubic close-packed lattice. The assumed coupling between next-neighbor molecules is the dominant term in the Coulomb interaction of two charge distributions of tetrahedral symmetry; coupling of

more widely separated molecules is neglected. A treatment of this system in the internal field approximation indicates that two types of orientational ordering may exist in such a crystal. At the lowest temperatures the orientational distribution function is the same for all molecules. At higher tempertures the stable type of order is one in which the crystal lattice is divided into eight sublattices, with all molecules on each sublattice having the same characteristic orientational distribution; molecules on two of these sublattices show no orientational ordering. At still higher temperatures the orientational ordering disappears completely. The lower transition is of the first order, the higher of second order. The predicted ratio of the transition temperatures agrees well with the observed ratio in CD_4, and the temperatures themselves are given correctly when one assumes a reasonable strength for molecular coupling.

FRIDAY AFTERNOON AT 1:30

Mechanical Building

(A. V. PHELPS presiding)

Gaseous Electronics and Atomic Physics, II

Invited Papers

(Z1 at beginning, Z2 after Z4)

Z1. Ionization-Probability Curves Using an Electron Selector. L. KERWIN, *Université Laval.* (25 min.)

Z2. Distribution Functions in High-Frequency Gas Discharges. A. D. MACDONALD, *Dalhousie University.* (25 min.)

Contributed Papers

Z3. Statistical Theory of Atomic Excitation by Electron Impact. Part I. Theoretical Development.* ROBERT W. HART, ERNEST P. GRAY, AND WILLIAM H. GUIER, *Applied Physics Laboratory, The Johns Hopkins University.*—A semiclassical statistical theory for atomic excitation by electron impact has been developed in terms of the Bohr-Sommerfeld atom. In spite of obvious disadvantages, this approach retains conceptual and analytical simplicity which are major reasons for the development of a statistical theory. In this theory, a volume in phase space, dependent upon the energy and angular momentum of the incident and excited electrons, is associated with the excitation of each level. It is assumed that: (1) Long after collision, the interelectron interaction can be neglected in calculating the phase volume for the excited and escaping electrons; (2) accessible phase space is restricted, therefore, to that part corresponding to independent particle orbits consistent with excitation of the specified level, and the energy and angular momentum constraints; (3) interelectron interaction establishes a uniform distribution in this phase space; and (4) excitation cross sections, therefore, are proportional to the corresponding phase volumes. The theory is somewhat analogous to a statistical treatment of bound motion in a Newtonian potential[1] and differs essentially from Boltzmann-Gibbs statistical mechanics in that the phase space includes only ordered motion.

* This work was supported by the Bureau of Ordnance, Department of the Navy, under NOrd 7386.
[1] R. W. Hart and W. H. Guier, Phys. Rev. **97**, 841 (1955).

Z4. Statistical Theory of Atomic Excitation by Electron Impact. Part II. Application to H and He.* ERNEST P. GRAY, ROBERT W. HART, AND WILLIAM H. GUIER, *Applied Physics Laboratory, The Johns Hopkins University.*—The statistical theory for atomic excitation presented in the previous paper is applied to calculating excitation cross sections for H and He for transitions involving no change in multiplicity. Results are compared with the Born approximation and, for He, also with experimental data (mainly from Burhop and Massey[1]). This comparison is made for relations between (1) cross sections for excitation of states having the same orbital quantum number, (2) cross sections for excitation of states having the same principal quantum number, and (3) cross sections for excitation of optically forbidden states and the elastic cross section. In (1), the statistical theory compares favorably with both Born approximation and experiment. In (2), it appears to be in somewhat better agreement with experiment than with the Born approximation. In (3), absolute cross sections are computed for *S*-states (in terms of the elastic cross section), and agree mostly within factors of two to three with both Born approximation and experiment. For optically forbidden transitions, the dependence on incident energy is the same as that of the Born approximation far above threshold. The significance of these results will be discussed.

* This work was supported by the Bureau of Ordnance, Department of the Navy, under NOrd 7386.
[1] H. S. W. Massey and E. H. S. Burhop, *Electronic and Ionic Impact Phenomena* (Oxford University Press, London, 1952).

Z5. Spectra of Low-Current Density Glow Discharges.* C. D. MAUNSELL, *Pacific Naval Laboratory.*—Spectra were taken of glow discharges having current density approximately 10^{-4} ampere/cm^2 in continuously flowing tank hydrogen, helium, nitrogen, and argon at pressures from 0.04 to 1.0 mm of mercury. At the lower pressures, separate spectra were obtained of the cathode glow, Crookes dark space, and negative glow. At higher pressure the first stria of the positive column was examined. For each gas the spectrum in the stria showed only systems of low-excitation energy. In the case of tank helium these were due to impurities. The negative glows showed the low-excitation features with additional lines and bands of higher exictation. The dark space and cathode glow showed chiefly high-excitation features. This seems to rule out for these discharges the hypothesis that the light of the cathode glow is due to electrons from the cathode exciting efficiently before they gain much energy from the field. The discharge tube was that used by Warren[1] for measurement of electric fields.

* This work was done at the University of California, Berkeley, with support from the Office of Naval Research.
[1] R. W. Warren, Phys. Rev. **93**, 943 (A), 1954.

Z6. Periodic Phenomena in Direct-Current Glow Discharges.* HARRY S. ROBERTSON, *University of Miami.*—Donahue and Dieke[1] have shown experimentally the almost universal presence of periodic oscillations of current, voltage, and light intensity in noble gas glow discharges having a positive column. These oscillations and moving striations are distinctly different from the plasma oscillations of Tonks and Langmuir,[2] as shown by Donahue and Dieke. An analysis has been made of the glow discharge, treating the ion concentrations as space- and time-dependent functions, periodic in time but not necessarily so in space. It is shown that because of the nonlinearity of the ion concentration equations, a steady-state calculation which ignores oscillatory terms is incorrect even for time-averages. A simplified, one-dimensional approximate calculation based on a two-stage ion-production process, in which the form of the metastable atom concentration is suggested by experimental evidence, will be discussed together with the possibilities of improving the calculation.

* Supported by an Office of Ordnance Research Contract.
[1] T. Donahue and G. G. Dieke, Phys. Rev. **81**, 248 (1951).
[2] L. Tonks and I. Langmuir, Phys. Rev. **33**, 195 (1929).

Z7. Gated Multiple Light Pulse Generator. RALPH D. DROSD, *Naval Ordnance Laboratory.*—An investigation was made of the limitations of producing short pulses of light at high-repetition rates from gaseous discharge tubes. At the beginning it was felt that the time of deionization was the limiting factor. Instead, it was found that very rapid pulses of light could be produced with the tube continuously ionized. A gated pulse generator was built to produce quarter microsecond pulses of light at the crystal controlled frequency of 200 000 per second. The light pulses were bright enough to photograph with a rotating mirror camera. Some evidence was found which indicated that repetition rates could be considerably higher.

Z8. Measurement of the Pumping Speed of an Ionization Gauge.* D. G. BILLS, F. G. ALLEN, AND N. P. CARLETON, *Harvard University.*—Although ionization gauge pumping is now extensively used for producing pressures of 10^{-10} mm Hg or less, no measurements of the pumping speed have been published so far as we know. We have experimentally determined the pumping speed of a Bayard-Alpert type WL5966 ionization gauge as a function of the quantity of nitrogen or oxygen which has been pumped. The pressure in the gauge was maintained constant during the measurements by means of a variable leak connecting the gauge to the gas source. The quantity pumped was determined from the decrease in pressure in the source and the pumping speed was calculated from measurements of the rate of decrease of pressure in the source. Our results for a clean gauge agree well with Alpert's[1] estimate of the maximum pumping speed for oxygen. The initial or maximum measured pumping speed for nitrogen is at least an order of magnitude greater than Alpert's estimate for nitrogen. The results of these measurements will be discussed.

* Supported in part by the Office of Naval Research, the Signal Corps of the U. S. Army, the U. S. Air Force, and the Air Force Cambridge Research Center.
[1] D. Alpert, J. Appl. Phys. **24**, 860 (1953).

Z9. Derivation Relating the Pumping Speed of an Ionization Gauge to the Quantity of Gas Pumped.* N. P. CARLETON AND D. G. BILLS, *Harvard University.*—The pumping speed of an ionization gauge depends upon the amount of gas which the gauge has pumped. To derive the relation between these quantities, we assume that there are present on the inside surfaces of a clean gauge a certain number of sites at which active particles can be adsorbed. These active particles may be ions, neutral atoms of certain gases such as O_2, or possibly metastables. When a given active particle strikes an open site, it has a certain probability of being adsorbed. If not adsorbed, it will be reflected unchanged. Similarly, when striking a site already occupied, the particle has a probability of being deactivated. If not deactivated, it will be reflected unchanged. Under these assumptions, whose validity will be discussed, we can derive a relation between the pumping speed of the gauge and the amount of gas pumped. The parameters in this relation are the initial, or maximum pumping speed, the maximum amount which can be pumped, and the relative probabilities of adsorption and deactivation. We shall compare our relation with experimental data, evaluating the parameters involved.

* This work was partially supported by the Air Force Cambridge Research Center.

Z10. Role of Re-emission in Ionic Pumping. L. J. VARNERIN, JR., AND J. H. CARMICHAEL, *Westinghouse Research Laboratories.*—The ionic pumping mechanism of helium in a Bayard-Alpert ionization gauge has been investigated. The reduction in pumping speed resulting in a nonexponential pressure reduction in a closed system is shown to result from the re-emission of helium previously pumped. The rate of re-emission was determined as a function of time from 0.5 min to 5000 min after pumping a small amount of gas for 0.5 min (pressure reduction Δp mm). The re-emission rate was found to be approximately $C(\text{mm/min}) = 0.04\Delta p(\text{mm})/t^{1.1}(\text{min})$ in this time interval. It is not possible in any simple way to account for this on the basis of gas diffusing to a surface into which the ions had been driven. This phenomenological equation for the re-emission of helium is used to derive an integro-differential equation applicable to the pumping process. Within the experimental accuracy of the data, the equation is shown to account quantitatively for observed pumping experiments in which pressure is reduced from 8×10^{-5} mm to 3×10^{-8} mm and the effective pumping speed reduces by a factor of 400.

SUPPLEMENTARY PROGRAMME

SP1. Radiation Flux Field Outside of Stars and Spherical Reactors. M. A. MELVIN, *The Florida State University.**—The energy density U, flux density F, and pressure P in the field of a hot spherical system, are here investigated along with their neutron-flux analogs. General expressions for U, F, and P are obtained and evaluated in particular (1) outside of spherical bodies radiating according to Lambert's law of isotropic radiance, I=constant, and (2) outside of stars or spherical reactors. Radiative (or transport) balance within a star (or reactor) leads to an angularly dependent radiance, $I(\cos\theta)$, from the outer surface. Assuming I to be given up to quadratic terms in $\cos\theta$, analytic expressions for U and P are obtained. It is further shown how one may use known exact numerical values for the radiance and its derivatives, at $\cos\theta=0$ and 1, to give still better analytic representations. For many purposes,[1] where one wishes to carry out calculations involving U or P, it is convenient to have simple analytic approximations for these quantities; such approximations are here given in the form of simple Lambert-law expressions multiplied by suitable factors.

* To be given at the end of Session W if the Chairman rules that time permits.
[1] M. A. Melvin, Phys. Rev. (to be published).

SP2. Fractional Occurrence Numbers of Eigenstates. M. A. MELVIN,* *The Florida State University.*†—A general class of eigenstate problems can be simulated in a zeroth-order approximation by harmonic vibrational problems with the same symmetry. Certain important aspects of the system such as the calssification of symmetry types of eigenstates and evaluation of the relative occurrence numbers of the symmetry adapted eigenstates are exactly given already in the zeroth-order approximation. Thus it is of general value to collect these results for systems with all possible symmetries. With the help of the Jahn-Teller table, based on Wigner's procedure, explicit tables for the fractional occurrence numbers in all the point symmetry groups are given. These have significance not only for systems with a finite number of particles (molecules) but also for continuous systems. The connection between fractional occurrence numbers and asymptotic densities of states of various symmetry types is indicated.

* Assisted by a contract with the U. S. Atomic Energy Commission, and by a grant from the Research Council of The Florida State University.
† To be given at the end of Session W if the Chairman rules that time permits.

SP3. Resiliency of Pure Metals. M. A. MELVIN AND J. W. BURGESON,* *The Florida State University.*†—A method for the measurement of coefficient-of-restitution (resiliency) e at low impact velocities has been developed. A light test body (sphere or cylinder) of the "impacted substance" is suspended pendularly. It is struck by a heavy rotating impactor upon whose striking face is mounted a plate of the "impacting substance." The impactor velocity is measured stroboscopically. The test body velocity is measured photoelectrically with an oscilloscope or an electronic timer. Results for various pairs of pure metals, e.g. Cu−Cu, Ti−Ti, Cu−Ti, Ti−Cu are given, and Raman's[1] hypothesis that e always approaches unity at low impact velocities is examined.

* Assisted by a grant of The Florida State University Research Council.
† To be given at the end of Session B if the Chairman rules that time permits.
[1] C. V. Raman, Phys. Rev. 12, 442 (1918).

SP4. Three-Dimensionality of Space and the Masses of Nuclei and Elementary Particles. ENOS E. WITMER, *University of Pennsylvania.**—The mass of any nucleus in any state may be represented by Mm, where m is the rest mass of the electron. The writer[1] has pointed out that the M-values for the lightest nuclei in the ground state are given to a very high degree of approximation, but not exactly, by a formula involving integers of which the first term is $(7/2)^*A$, where A is the number of nucleons in the nucleus. Even for the heavier nuclei the writer[2] has found interesting results of the same type. Since $6=2\times3$ and $7/2=3+1/2$, the number 3 appears to be important here. Therefore, we propose the idea that the characteristics of nuclei and elementary particles should not be explained ultimately by reference to more elementary particles and the forces between them, but by a unitary theory giving all particle and nuclear masses in one operation and in which the nature of space-time plays a more important role than is envisaged today. Since space is three-dimensional, this could account for the importance of the foregoing number 3.

* To be given at the end of Session S if the Chairman rules that time permits.
[1] E. E. Witmer, Phys. Rev. **95**, 610 (1954).
[2] E. E. Witmer, Bull. Am. Phys. Soc. **30**, No. 1, 35 (1955).

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The Future of *The Physical Review*

AS was expected, *The Physical Review* is still growing. Judging by the volume of articles received to date, the year 1955 will see about 1000 more printed pages than 1954. Some way must be found to reduce the publication load. This might be done either by creating a new journal or by obtaining additional financial support for other journals so that they can improve their publication schedules and assume part of the load. Over these other journals the American Physical Society has no control.

The plan to split *The Physical Review* into two monthly journals, even the present tentative alternate-subject scheme, turned out to be unsatisfactory. Several authors praised the tentative scheme but claimed that their own paper was scheduled for the section "which nobody in this field reads." Even though this is true for both sections if for either, it became obvious that one would grow at the expense of the other, like two connected balloons, and would become unmanageable. Authors also considered it undesirable that papers and proofs reaching us just after a deadline would be delayed by four instead of two weeks.

Fewer than ten percent of the membership returned the opinion ballot printed in the January *Bulletin*. Therefore, no certain conclusion could be derived from the result, except that there is most likely a need for a journal that specializes more in solid state physics and related topics.

At present it is unfortunately necessary to increase the so-called page charge to $25 per page. The charge for Letters is also to be $25 per page with a minimum of $25 per Letter. These will go into effect with the issue of July 1, 1955. Beginning January 1, 1956, the subscription rates will be increased from $5 to $10 for members and from $30 to $40 for nonmembers. In spite of these measures we still expect an operating deficit of $30 000 in 1955.

Beginning in 1956, the *Bulletin* of the American Physical Society will assume a new role. Its contents no longer will be reprinted in *The Physical Review*, and it will contain a yearly author index. It will still be distributed free to members and at $5 per year to nonmembers. At meetings, a sufficient number of copies will be available free to those registered so that everyone can keep one copy for permanent record.

In future the *Bulletin* also will be used frequently for announcements and other communications which will keep the membership informed about the problems of our Society.

This new policy for the *Bulletin* also will provide further relief for the "Letters to the Editor" column of *The Physical Review*. The processing of such Letters is far more cumbersome than most authors realize. The column should thus be restricted to communications for which rapid publication is essential. The difference in publication time between Letters and Articles is only six weeks. That a communication is short does not necessarily imply that it deserves special handling. The editorial policy will continue to be moderately lenient in this matter, however, and consequently somewhat arbitrary and inconsistent. But we wish to make it a policy that new results should not be published both as an abstract in the *Bulletin* and as a "Letter to the Editor."

Samuel A. Goudsmit
Managing Editor

May 1955

The American Physical Society

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